Louisville Metro

Multi-Hazards Mitigation Plan

SECTION 3.0 RISK ASSESSMENT

TABLE OF CONTENTS

3.0 RISK ASSESSMENT 5
3.1 Identifying Hazards 6
3.1.1 Multi-Hazards Identified in the Louisville Metro Plan 7
3.1.2 Louisville Metro Hazard Vulnerability Overview 8
3.1.2.1 Louisville Metro Climate 8
3.1.2.2 Louisville Metro Geology 9
3.1.2.3 Kentucky Topography 10
3.1.2.4 Louisville Metro Topography 11
3.1.2.5 Louisville Metro Watersheds 12
3.1.2.6 Endangered Species in Louisville 12
3.2 Hazard Profile Introduction 14
3.2.1 Major Disaster Declarations in Kentucky (1957 – May 2010) 14
3.2.2 Profiling Hazards 16
3.2.2.1 Hazard Risk Gauge 16
3.2.3 Assessing Vulnerability: Overview 17
3.2.3.1 Vulnerability Assessment Methodology 17
3.2.3.2 Model 18
3.2.3.3 Definitions of Variables to Determine Exposure Score 18
3.2.3.4 Definitions of the Risk Score 20
3.2.4 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses 21
3.2.4.1 Loss Estimation Methodologies 22
3.2.4.2 Hazard Boundary Overlay Loss Estimate Model 22
3.2.4.3 Average Annualized Loss Estimate Model 23
3.3 Dam / Levee Failure 26
3.3.1 Dam / Levee Failure Profile 30
3.3.1.1 Assessing Vulnerability Overview: Dam/Levee Failure 33
3.3.1.2 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: Dam/Levee Failure 35

3.4 Drought....36
3.4.1 Drought Profile....39
3.4.1.1 Assessing Vulnerability Overview: Drought....43
3.4.1.2 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: Drought....44
3.5 Earthquake....45
3.5.1 Earthquake Profile....50
3.5.1.1 Assessing Vulnerability Overview: Earthquake....55
3.5.1.2 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: Earthquake....57
3.6 Extreme Heat....58
3.6.1 Extreme Heat Profile....61
3.6.1.1 Assessing Vulnerability Overview: Extreme Heat....64
3.6.1.2 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: Extreme Heat....65
3.7 Flood....66
3.7.1 Flood Profile....70
3.7.1.1 Repetitive Loss Areas....79
3.7.1.2 Assessing Vulnerability Overview: Flood....81
3.7.1.3 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: Flood....84
3.7.2 Louisville Metro's Watersheds....85
3.7.2.1 Watershed Characteristics....86
3.7.2.2 Flood Hot Spots....87
3.7.2.3 Watershed Flood Risk....87
3.7.2.4 Natural and Beneficial Floodplain Functions....88
3.7.2.5 Critical Facilities in a Floodplain....89
3.7.3 Watershed Overviews....90
3.7.3.1 Ohio River/City Watershed....90
3.7.3.2 Middle Fork Watershed – Beargrass Creek....93
3.7.3.3 Muddy Fork Watershed – Beargrass Creek....96
3.7.3.4 South Fork Watershed – Beargrass Creek....99
3.7.3.5 Cedar Creek Watershed....103
3.7.3.6 Floyds Fork Watershed....105
3.7.3.7 Goose Creek Watershed....108
3.7.3.8 Harrods Creek Watershed....111
3.7.3.9 Mill Creek Watershed....114
3.7.3.10 Pennsylvania Run Watershed....118
3.7.3.11 Pond Creek Watershed....121
3.7.3.12 Basic Watershed Flood Information....126

3.8 Hail 127
3.8.1 Hail Profile 128
3.8.1.1 Assessing Vulnerability Overview: Hail 129
3.8.1.2 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: Hail 131
3.9 Hazardous Materials (HAZ/MAT) 132
3.9.1 Hazardous Materials (HAZ/MAT) Profile 133
3.9.1.1 Assessing Vulnerability Overview: HAZ/MAT 135
3.9.1.2 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: HAZ/MAT 137
3.10 Karst/Sinkhole 138
3.10 Karst/Sinkhole Profile 142
3.10.1 Assessing Vulnerability Overview: Karst/Sinkhole 145
3.10.1.2 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: Karst/Sinkhole 147
3.11 Landslide 148
3.11.1 Landslide Profile 150
3.11.1 Assessing Vulnerability Overview: Landslide 154
3.11.2 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: Landslide 156
3.12 Severe Storm 157
3.12.1 Severe Storm Profile 159
3.12.2 Lightning 161
3.12.3 Lightning Profile 163
3.12.3.1 Assessing Vulnerability Overview: Severe Storm 164
3.12.3.2 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: Severe Storm 166
3.13 Severe Winter Storm 167
3.13.1 Severe Winter Storm Profile 169
3.13.1.1 Assessing Vulnerability Overview: Severe Winter Storm 174
3.13.1.2 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: Severe Winter Storm 175
3.14 Tornado 176
3.14.1 Tornado Profile 181
3.14.1.1 Assessing Vulnerability Overview: Tornado 183
3.14.1.2 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: Tornado 185
3.15 Wildfire 186
3.15.1 Wildfire Profile 189
3.15.1.1 Assessing Vulnerability Overview: Wildfire 191
3.15.1.2 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: Wildfire 193

3.16 Assessing Vulnerability: Analyzing Development Trends....194
3.16.1 Population Trends....194
3.16.2 Landuse....195
3.16.3 Development Trends....196
3.17 Hazard Ranking and Risk Matrix....198

SUPPORTING INFORMATION

Appendix 3.1 Exposure Score Maps
Appendix 3.2 HAZUS 500 Year Probabilistic Earthquake run

3.0 RISK ASSESSMENT

The hazard identification section identifies the 13 hazards likely to affect the Louisville Metro area and outlines historical record of damage and disaster declarations. Section 3 provides an overview of Louisville's climate, geology, topography, watersheds, and endangered species.

This section profiles the hazards by providing background information on U.S. and Kentucky impacts, local damage history, and provides a risk factor table and hazard risk gauge that summarizes the overall risk. The profiles provide a description on the potential impacts and the probability and magnitude for each identified hazard. The profiles also focus on severity and resulting affects on transportation, safety, and economics.

The individual risk assessment sections for all 13 hazards provide a comprehensive overview. Throughout the Risk Assessment, maps are used whenever possible to convey where the spatial data and at-risk areas are located. Maps provide an invaluable Geographic Information Systems (GIS) visual tool for analysis and are a key component for communication with the Advisory Committee, Metro Council, and at public meetings. Data, maps, research, and guidance were developed using the best available data and the approved 2007 Kentucky Hazard Mitigation Plan, as well as many other sources, see References.

The 2011 Louisville Metro Multi-Hazards Mitigation Plan update is a product of standardizing processes. The Risk Assessment section has been redesigned from the 2005 Plan to enhance the flow of the information provided throughout the section so that a holistic analysis and review is completed for Louisville Metro's vulnerabilities. The Plan needs to be updated for several reasons, but mainly because of former limited data sources.

> **Risk Assessment**
>
> §201.6(c)(2) requires local jurisdictions to provide sufficient information from which to develop and prioritize appropriate mitigation actions to reduce losses from identified hazards.
>
> This includes detailed descriptions of all the hazards that could affect the jurisdiction along with an analysis of the jurisdiction's vulnerability to those hazards. Specific information about numbers and types of structures, potential dollar losses, and an overall description of landuse and development trends should be included in this analysis.

FEMA's plan review tool, the Crosswalk, specifically outlined deficiencies in the 2005 Plan and the updated Risk Assessment provided an opportunity to update the Plan to address the deficiencies. As a result, the Risk Assessment provides an analysis for Louisville Metro's vulnerabilities, including identifying assets, estimating potential losses, establishing current landuses, and analyzing population and development trends.

Better Available Data. While developing the 2005 Plan, best available data was used for the Risk Assessments. To upgrade and update the Plan, better or more detailed data was required in order to better utilize local GIS capabilities and to perform an accurate risk assessment to indicate the vulnerability of developed areas. Specifically, better data allows Louisville Metro to enhance their vulnerability assessment and improve their mitigation action identification process. The Assessing Vulnerability sections show an enhanced vulnerability model from the model in the 2005 Plan. This model was an intricate part in defining Assessing Vulnerability of Structures, Estimating Potential Losses, and with the Analyzing Development Trends.

3.1 Identifying Hazards

During the process of "Hazard Identification", members of the Project Staff used GIS resources to identify hazards that affect the area. Project Staff researched current hazard data, reports, plans, flood ordinances, past hazard events, flood insurance claims, land use regulations for hazard data, local records of the Emergency Management offices, local newspapers, historical knowledge of committee participants, local officials and community members, as well as GIS information from LOJIC and HAZUS-Multi-Hazards (MH). Members of the Advisory Committee provided rich sources of data. Project Staff also talked to experts from federal, state, regional, local agencies and universities.

Additional research used to identify hazards included interviews of knowledgeable officials and residents in the planning area, the use of FEMA and other web based databases and information sources that identify hazards by geographic locations, Corps of Engineers flood data, Digital-Flood Insurance Rate Maps (D-FIRM), Flood Insurance Studies (FIS), GIS, and additional available historic data including information on past hazard events.

A list of U. S. natural hazards includes:

- Avalanche
- Coastal Storms
- Dam Failure
- Drought
- Earthquake
- Extreme Heat
- Flood
- Hailstorm
- Hurricane
- Mine Subsidence
- Severe Winter Storm
- Tornado
- Tsunami
- Volcano
- Wildfire
- Windstorm

Natural Hazards not Identified in the Louisville Metro Plan

Some natural hazards have little or no affect on the Louisville Metro area or in Kentucky and will not be addressed in this plan. The hazards showed negligible impact and were not part of federal disaster declarations. This determination does not preclude the plan from including these hazards in future updates of the plan as new information is discovered concerning these types of hazards. Any new information on hazard identification will be included in future updates of this Plan. Following are the natural hazards that will *not* be addressed in the Louisville Metro Multi-Hazard Mitigation Plan.

Avalanche: The topography and climate of the Louisville Metro area are not conducive to the occurrence of avalanches. No historical events have been recorded in the Louisville Metro area; and, as a result, this hazard will not be addressed in the plan.

Coastal Storms: The Louisville Metro area is more than 400 miles from the Gulf of Mexico coast and over 500 miles from the Atlantic Ocean coast. The immediate effects of coastal storms (hurricanes, storm surge and tsunamis) are not felt in the Louisville Metro area. The secondary effects or remnants of hurricanes may produce severe thunderstorms and flooding in the Louisville Metro area and those hazards will be addressed.

Mine Subsidence: Mine subsidence is defined as the collapse of underground coalmines resulting in direct damage to a surface structure. Land subsidence occurs when the ground sinks to a lower than normal level. Louisville Metro has no active mines and will cover the topic of Land Subsidence under Karst/Sinkholes.

Volcanoes: More than 50 volcanoes in the U. S. have erupted one or more times in the past 200 years. Volcanoes produce a wide variety of hazards that can kill people and destroy property. Active volcanoes in North America are in California, Oregon, Washington, Alaska, Mexico, Canada, and the Caribbean islands. Large explosive eruptions can endanger people and property hundreds of miles away and even affect global climate. However, there are no active volcanoes within 1,000 miles of the Louisville Metro area. Volcanic activity as a hazard is judged to be minimal and will not be addressed in this plan.

3.1.1 Multi-Hazards Identified in the Louisville Metro Plan

The Plan includes natural hazards where there is a historical record of damage caused to people and property or where the potential for such damage exists. Due to Louisville's climate, geology, and geographical setting, the metro area is vulnerable to a wide array of natural hazards that threaten life and property. Man-made hazards were added to the 2011 plan which created the multi-hazard approach. Hazardous Materials (HAZ/MAT) was added as an identified hazard for Louisville Metro.

Through research of the Louisville Metro Emergency Operations Plan (EOP), historic impacts, past federal disaster declarations, probability rates, dollar losses to date, State Hazard Mitigation Plan and discussions with key agencies, the following thirteen hazards are identified in the Plan. The multi-hazards, in alphabetical order, include:

- Dam/Levee Failure
- Drought
- Earthquake
- Extreme Heat
- Flood
- Hailstorm
- HAZ/MAT
- Karst/Sinkhole
- Landslide
- Severe Storm
- Severe Winter Storm
- Tornado
- Wildfires

3.1.2 Louisville Metro Hazard Vulnerability Overview

Natural hazards in the U. S. occur in many forms. They can be weather related such as flash floods, severe storms (hail, wind, & tornados), severe winter storms (snow, ice, & frigid temperatures), and coastal storms (hurricanes, storm surges, & tsunamis).

- Climatological hazards include drought, excessive heat, and wildfires.
- Geological hazards include volcanoes, earthquakes, karst/sinkholes, and landslides.
- Topography and hydrology can affect riverine flooding from upstream rain or snow events.
- Man made dams, dikes, and floodwalls can be a source of inundation or flooding if they fail.

The following sections are a review of Kentucky and Louisville's vulnerability to climate, geology, topography, floodplain, watersheds, and endangered species.

3.1.2.1 Louisville Metro Climate

The U.S. Natural Hazard Statistics provide statistical information on fatalities, injuries, and damages caused by weather related hazards. These statistics are compiled by the Office of Services and the National Climatic Data Center (NCDC) from information contained in *Storm Data*, a report comprising data from NWS forecast offices in the 50 states, Puerto Rico, Guam, and the Virgin Islands.

Louisville's climate is described as "moist-continental". Winters are moderately cold with temperatures rarely below zero degrees Fahrenheit, with January being the coldest month.

Average annual snowfall is about 17 inches. Summers are hot (although rarely above 100 degrees Fahrenheit) and humid, with July being the hottest month. Spring and summer months are characterized by changeable, wet weather. March has the greatest total rainfall. Yearly precipitation is approximately 43 inches. The driest month is October.

Louisville Climatology	
Average High Temperature	66° F
Average Low Temperature	48° F
Average Temperature	57° F
Average Dew Point	47° F
Normal Number of Days ≥ 90°	33 days
Normal Number of Days with High ≤ 32°	18 days
Normal Number of Days with Low ≤ 32°	83 days
Normal Number of Days with Low ≤ 0°	1 day

The climate of Louisville, while continental in type, is of a variable nature because of its position with respect to the paths of high and low pressure systems and the occasional influx of warm moist air from the Gulf of Mexico. In winter and summer, there are occasional cold and hot spells of short duration. As a whole, winters are moderately cold and summers are quite warm.

Month	Normal Average Temperature
January	33° F
February	38° F
March	47° F
April	56° F
May	66° F
June	74° F
July	78° F
August	77° F
September	70° F
October	59° F
November	48° F
December	38° F

Temperatures of 100 degrees or more in summer and zero degrees or less in winter are rare. Thunderstorms with high rainfall intensities are common during the spring and summer months. The precipitation in Louisville is nonseasonal and varies from year to year. The percentage of possible sunshine varies from month to month with the greatest amount during the summer months as a result of the decreasing sky cover during that season. Heavy fog is unusual and there is only an average of 10 days during the year with heavy fog and these occur generally in the months of September through March.

Snowfall usually occurs from November through March. As with rainfall, amounts vary from year to year and month to month. Some snow has also been recorded in the months of October and April. Mean total snowfall for the months of January, February, and March are about the same with January showing a slight edge in total amount.

NWS Data Normal Precipitation	44.54 inches
Normal Number of Days with ≥ 0.01" Precipitation	126 days
Normal Number of Days with ≥ 1.00" Precipitation	11 days
Normal Snowfall	14.6 inches
Normal Number of Days with ≥ 0.1" Snow	11 days
Normal Number of Days with ≥ 1.0" Snow	4 days
Normal Number of Days with ≥ 2.0" Snow	2 days

Relative humidity remains rather high throughout the summer months. Cloud cover is about equally distributed throughout the year with the winter months showing somewhat of an increase in amount. The average date for the last occurrence in the spring of temperatures as low as 32 degrees is mid-April, and the first occurrence in the fall is generally in late October.

3.1.2.2 Louisville Metro Geology

Geologic hazards, such as earthquakes, landslides, and sinkholes, cause millions of dollars in losses in Kentucky each year. The level and type of geologic hazards vary across the state, depending on the geology, topography, and hydrology.

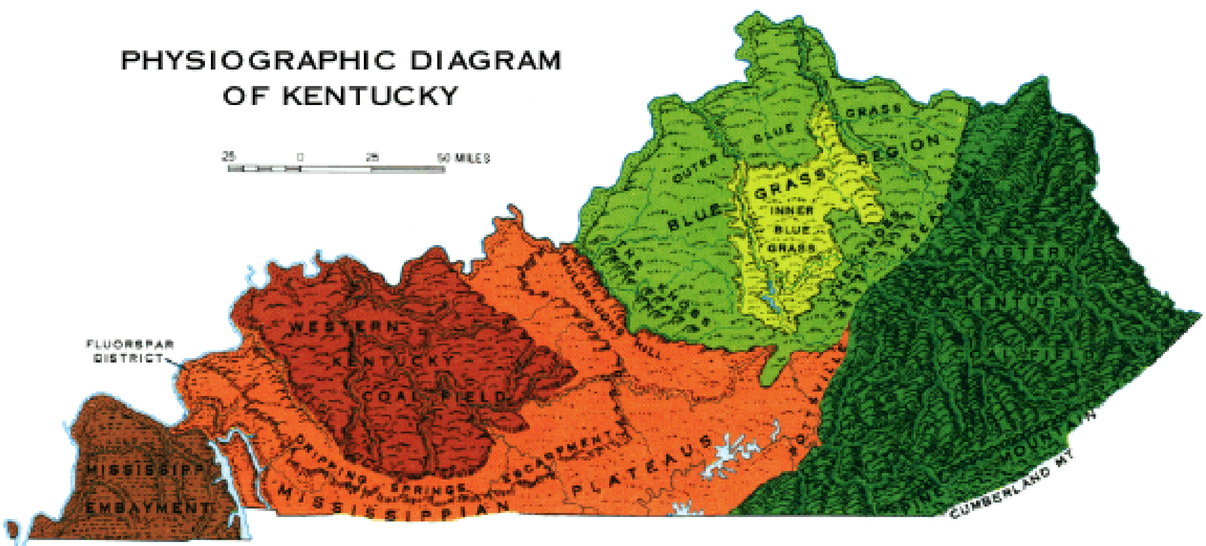
For Louisville Metro, the geology consists of limestone, shale, and dolomite plus alluvial and lacustrine deposits. The five major geological areas are as follows:

1. The loam soils in the northeastern part of the county tend to overlie limestone, are relatively deep, and generally well drained. They are best suited for pasture.
2. The northern and western most parts of the county are adjacent to the Ohio River. The soils found within this area are well-drained alluvial soils with a silty sand texture. These floodplain soils represent some of the best agricultural soils in the county.
3. The central portion of the county is in poorly drained clay-based soils. Much of this area was once considered a wetland.

4. The geology within the southern part of the county is on steep slopes or upland areas. The soils are generally well-drained, moderate in depth, composed of shaly limestone or silty loam, and are best used for maintaining forested areas.
5. The southeastern part of the county is mostly hills, with moderate to steep slopes, and numerous sinkholes. The soils overlie limestone, and limestone fragments are commonly mixed into the soils. The soils are moderate to deep in most areas, generally well drained, and are a mixture of windblown sediments, silt, loam, and clays. They are well suited for forest and pasture.

3.1.2.3 Kentucky Topography

Kentucky can be divided into five major physiographic regions (which can be further subdivided): the Mississippi Embayment or Jackson Purchase in the west, the Mississippian Plateaus or Pennyrile, the Western Coal Field, the Bluegrass, and the Eastern Coal Field. See the KGS map below.



Kentucky Geological Survey, undated

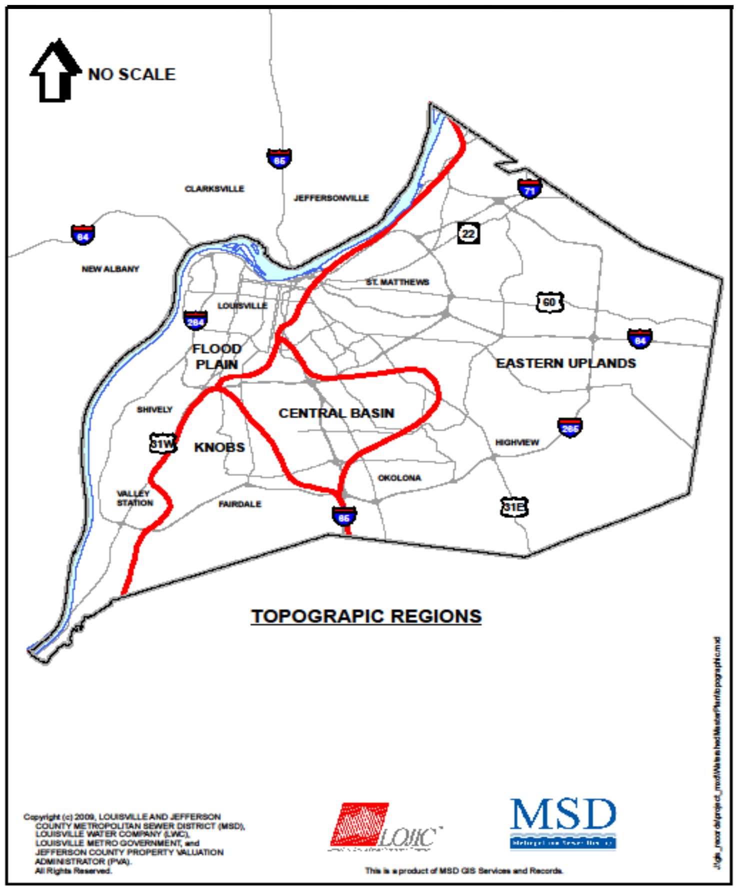
The Bluegrass region of Kentucky is located near the center of the state and is bordered by the Ohio River in the north and west and a ring of hills known as the Knobs in the west, south, and east. It is a rolling plateau that becomes more rugged near the edges. The underlying limestone is often visible at the surface in road cuts and where eroded by streams, most dramatically in the Kentucky River Palisades. The Bluegrass region was the most quickly settled part of the state and now is home to about half the state's population. The largest cities, including Louisville, Lexington, and the urban area of northern Kentucky are located here.

The map shows the extent of Kentucky's physiographic regions, the distribution of prominent topographic features that border the regions, and the general trend of major rivers. The names of some regions, such as the Knobs and the Plateaus, are descriptive; other regions, such as the Bluegrass, Jackson Purchase, and Western Coal Field, are not named for their landforms but are nevertheless well-recognized geographic areas with common socioeconomic histories related to their natural resources. Each region is characterized by distinctive landscapes produced by erosion and deposition of different rock types.

3.1.2.4 Louisville Metro Topography

Four distinct topographic regions exist in Louisville Metro as the map shows of the regions. The four areas include Flood Plain, Knobs, Central Basin, and Eastern Uplands.

The "Flood Plain" is a strip of land bordering one-half to five miles wide along the Ohio River. The Flood Plain extends from the Salt River in the southwest, north to downtown Louisville, and continues northeast to the Oldham County line. The lowest elevations in the county are found in this region and generally range from 430 to 440, with occasional terraces to 460. The area is best characterized as flat to gently rolling and with very flat sloped stream beds. Mill Creek and the combined sewer system drain the majority of this region.



The "Knobs" region covers a triangular area in the southwestern portion of the county bounded approximately by Iroquois Park on the north, South Park Hills on this southeast, and the Southern Railroad on the southwest. The hills in this region have been highly dissected by stream erosion. Side slopes of 30% to 50% are common, and this region contains the highest elevations in the county, probably approaching the level of the original Appalachian Plateau. These steep sided hills rise 300 to 400 feet above their surroundings and numerous streams originate here. The majority of these streams drain to Pond Creek, which has eroded a trench, effectively bisecting this region from east to west.

The west central portion of the county, bounded approximately by I-264 on the north, Shepherdsville Road on the east, and the "Knobs" region on the south and west, is the "Central Basin." This is a former slack-water region of shallow soils and nearly flat terrain with elevations ranging between 450 and 500. Various improvements to the Northern and Southern Ditch systems have helped alleviate the lack of natural drainage in the region.

The “Eastern Uplands” cover the remainder and largest portion of the county. This region is characterized by gently rolling to hilly plains to moderate to very steep valleys. Elevations range between 500 and 800. Goose Creek, Harrods Creek, Floyds Fork, and the Beargrass Creek system drain this region.

3.1.2.5 Louisville Metro Watersheds

In Louisville Metro, approximately 790 miles of streams are drained into eleven major stream systems. These eleven major stream systems in Louisville Metro’s watersheds are:

- Cedar Creek
- Floyds Fork
- Goose Creek
- Harrods Creek
- Middle Fork Beargrass Creek
- Mill Creek
- Muddy Fork Beargrass Creek
- Ohio River
- Pennsylvania Run
- Pond Creek
- South Fork Beargrass Creek

3.1.2.6 Endangered Species in Louisville

Endangered means the species is in imminent danger of extinction throughout all or a large part of the range. Following is a list endangered species in Louisville Metro.

Mammals

- Gray Bat: Restricted to caves or cave-like habitats with deep vertical passages with large rooms that function as cold air traps.
- Indiana Bat: A small bat that prefers limestone caves.

Birds

- Peregrine Falcon: Crow-sized and a high-speed flyer with superior eyesight. Primarily found along rivers and lakes, where cliffs or a series of cliffs dominate the landscape. In Kentucky, found only in Louisville Metro.

Mussels

- Fanshell: Found in medium sized to large rivers of the Ohio River basin and occurs in coarse sand and gravel substrates and prefers moderate to swift currents,
- Pink Mucket: Found in the medium to large rivers with moderate to fast flowing currents.
- Ring Pink: Large river species is found on gravel bars in swift water and prefers relatively shallow water with a sand or gravel substrate.

- Orange-Foot Pimpleback: Large river species is usually found in 15 to 20 feet of water. This species burrows in sand or gravel substrates.
- Clubshell: Large river species usually found burrowed 2 to 4 inches below the surface in clean sand and gravel.
- Fat Pocketbook: Large river species usually found in backwater areas with muddy or sandy substrates.

Plants

- Running Buffalo Clover: A member of the pea family and a perennial clover. In Kentucky, occurs exclusively in the Bluegrass Region. Habitat ranges from stream banks and low moist forests to successional areas in mesic forests.

3.2 Hazard Profile Introduction

As noted in the last section, due to Louisville's geology, climate, and geographical setting, the metro area is vulnerable to a wide array of natural hazards that threaten life and property. The following section profiles those hazards previously identified as affecting Louisville (see section titled, Identifying Hazards).

Update to the Risk Assessment

During an update to the risk assessment, local jurisdictions consider current and expected future vulnerability to all hazards and to integrate new hazard data such as flood studies. Local jurisdictions are encouraged to incorporate updated estimates of cost of living and replacement costs for vulnerable buildings, reduced vulnerability due to the completed mitigation actions or projects, and impacts of population growth or loss in vulnerable areas.

The Louisville Metro Hazard Profiles have been created using the best available data from a variety of resources, including but not limited to the National Climatic Data Center (NCDC), National Weather Service (NWS), LOJIC, Corps of Engineers: Louisville District, Kentucky Office of Geographical Information, Kentucky Geological Survey (KGS), Kentucky State Climatology Center, Midwestern Regional Climate Center (MRCC), FEMA Hazard Mapping website, local agencies and newspaper articles, and the approved 2007 Kentucky State Hazard Mitigation Plan.

Project Staff used the FEMA Local Mitigation planning "How to Guide" series to guide the Advisory committee in the planning process. GIS hazard maps, damage history spreadsheets, and historical documentation are used to profile each event.

During the planning process, public input from the Advisory Committee led to the creation of Profile Maps that document and illustrate where the Hazard prone areas are in Louisville Metro. Public input was an invaluable local resource in the planning process. Committee members attended meetings and discussed information gathered from the sources listed above. Committee members also discussed particular issues such as, past events and significant occurrences that did not warrant a declared disaster and how those events impacted the community.

Louisville Metro
Vulnerable to 13 Hazards

- Dam Failure
- Drought
- Earthquake
- Extreme Heat
- Flooding
- Hailstorms
- Hazardous-Materials
- Karst / Sinkholes
- Landslides
- Severe Storm
- Tornados
- Wildfire
- Winter Storms

3.2.1 Major Disaster Declarations in Kentucky (1957 – May 2010)

Past disaster damage information was provided to Project Staff by the Kentucky Emergency Management (KyEM) state hazard mitigation office and FEMA. The following table is the Kentucky list of past Declared Disasters. Throughout the plan, reference will be made to this table as the hazard events are profiled.

Red denotes the inclusion of Louisville Metro in three disaster declarations since the 2005 Natural Hazards Mitigation Plan was adopted. Aqua represents declarations in Louisville Metro prior to the 2005 Plan.

Year	Date	Disaster Types	Disaster Number
2010	05/11	Severe Storms, Flooding, Mudslides, And Tornadoes	1912
2009	08/14	Severe Storms, Straight-Line Winds, And Flooding	1855
2009	05/29	Severe Storms, Tornadoes, Flooding, And Mudslides	1841
2009	02/05	Severe Winter Storm And Flooding	1818
2008	10/09	Severe Wind Storm Associated With Tropical Depression Ike	1802
2008	05/19	Severe Storms, Tornadoes, Flooding, Mudslides, And Landslides	1757
2008	02/21	Severe Storms, Tornadoes, Straight-Line Winds, And Flooding	1746
2007	05/25	Severe Storms, Flooding, Mudslides, And Rockslides	1703
2005	12/01	Severe Storms And Tornadoes	1617
2005	02/08	Severe Winter Storm And Record Snow	1578
2004	08/06	Severe Storms And Flooding	1537
2004	06/10	Severe Storms, Tornadoes, Flooding, And Mudslides	1523
2003	07/02	Severe Storms, Flooding, Mud And Rock Slides, And Tornadoes	1475
2003	06/03	Severe Storms, Flooding, Mud And Rock Slides, And Tornadoes	1471
2003	03/14	Severe Winter Storms	1454
2002	05/07	Severe Storms, Tornadoes And Flooding	1414
2002	04/04	Storms And Flooding	1407
2001	08/15	Severe Storms & Flooding	1388
2000	02/28	Severe Storms And Flooding	1320
2000	01/10	Tornadoes, Severe Storms, Torrential Rains And Flash Flooding	1310
1998	04/29	Severe Storms, Tornadoes And Flooding	1216
1998	03/03	Severe Winter Storm	1207
1997	03/04	Severe Storms/Flooding	1163
1996	06/01	Severe Storms/Tornadoes	1117
1996	01/13	Blizzard	1089
1995	06/13	Severe Storm, Tornadoes, Hail	1055
1994	03/16	Severe Storm, Freezing Rain, Sleet, Snow	1018
1991	01/29	Flooding, Severe Storm	893
1989	10/30	Severe Storms, Mudslides, Flooding	846
1989	06/30	Severe Storms, Flooding	834
1989	02/24	Severe Storms, Flooding	821
1984	05/15	High Winds, Tornadoes, Flooding	705
1982	09/29	Flash Flooding	670
1981	03/17	Sewer Explosion, Toxic Waste	636
1979	07/19	Severe Storms, Flash Floods	592
1978	12/12	Severe Storms, Flooding	568
1977	04/06	Severe Storms, Flooding	529
1975	05/24	Severe Storms, Flooding	468
1975	03/29	Severe Storms, Flooding	461
1974	04/04	Tornadoes	420
1973	05/11	Severe Storms, Flooding	381
1972	05/15	Heavy Rains, Flooding	332
1971	05/10	Tornado	305
1970	06/05	Severe Storms, Flooding	288
1970	02/02	Heavy Snowmelt, Rains, Flooding	282
1969	07/15	Severe Storms, Flooding	265
1968	05/04	Tornadoes, Severe Storms	237

Year	Date	Disaster Types	Disaster Number
1967	03/27	Severe Storms, Flooding	226
1964	03/17	Severe Storms, Flooding	163
1963	03/13	Severe Storms, Flooding	148
1962	03/12	Floods	128
1957	01/31	Flood	66

http://www.fema.gov/news/disasters_state.fema?id=21

3.2.2 Profiling Hazards

How the Profiles Are Set Up: The following sections provide a "profile" of each identified hazard in the Louisville Metro area.

This portion of the plan identifies the following information:

- A risk factor table and hazard risk gauge, which summarize the overall risk.
- A description of each identified hazard and potential impact.
- Historical background on each identified hazard and a brief description of known events.
- Profile Maps, if applicable, of the locations and areas affected by Hazard events.
- Vulnerability Assessment with number of structures affected, potential losses, and development trends.

Maps are a key component for communication with the Advisory Committee, Metro Council, and at the public meetings. Hazard maps also will assist in determining the mitigation strategy.

Profiling the hazard includes identifying the location, extent, previous occurrences, and the probability of future events for each hazard. Project Staff created a standardized "Risk Factor Table" for each of the hazards. The tables provide a standardized view of each hazard and a general understanding of the risk each hazard has on the community and captures the following data elements:

- Period of Occurrence
- Number of Events to Date
- Probability of Events
- Warning Time
- Potential Impacts
- Past Damages

3.2.2.1 Hazard Risk Gauge

Also included in the profile section is the ***hazard risk gauge*** which is a graphic icon used during the initial profile ranking process to convey the relative *risk extent* of a given hazard.

3.2.3 Assessing Vulnerability: Overview

The Assessing Vulnerability section uses best available data from national, state, and local data sources. The vulnerability assessment methodology was created using best available data and modeling techniques. The model used for the Louisville Metro plan follows the State's Vulnerability Assessment Model and the 2005 Louisville Metro Natural Hazard Mitigation Plan.

This model is very flexible and can be adjusted to fit the data and needs of multiple users. These estimates provide an understanding of relative risk and potential losses from hazards. Uncertainties are inherent in any vulnerability assessment and loss estimation methodology, arising in part from incomplete scientific knowledge concerning natural and man-made hazards and their effects on the built environment. Uncertainties can also result from approximations and simplifications that are necessary for a comprehensive analysis (such as incomplete inventories, demographics, or economic parameters).

The 2010 Vulnerability Assessment incorporates superlative models in use and integrates them into a specific model. FEMA requires State and Local partners to assess the jurisdiction's overall vulnerability to population, property, infrastructure, critical facilities, and government owned facilities. The Project Staff, using the best available data and methods, determined vulnerability of Louisville Metro for the hazards identified (see Identifying Hazards Section).

A critical step in creating a Vulnerability Assessment Model is to define the planning area. During the creation of the 2005 plan Louisville Metro used a census tract level assessment. The census tract level modeling technique provided detailed assessments for highly populated areas of the county but this approach still left some deficiencies in less populated areas of the county. The 2010 plan has taken the next step by creating a vulnerability assessment at the census block level. This model produced the following improvements:

1. Better hazard scenario assumptions
2. Better dollar allocation
3. Better policy decisions
4. Better visuals
5. Better tool for locals

LOJIC and Project Staff used the census block data and demographic tables from LOJIC GIS to define the planning areas, which produced 9,965 separate planning areas (blocks) across the Louisville Metro planning area. Census Blocks are the smallest geographic unit used by the U.S. Census Bureau for tabulation of 100-percent data (data collected from all households).

3.2.3.1 Vulnerability Assessment Methodology

There is no single way to determine hazard vulnerability. FEMA provides users with its HAZUS-MH software to perform vulnerability assessments. However, there are some major limitations in using HAZUS-MH for Louisville Metro. The data in HAZUS-MH poses limitations for Louisville Metro due to its lack of local data inventory and hazard assessment limitations. HAZUS-MH produces vulnerability assessments for flood, earthquake, and hurricane. The flood model is still somewhat cumbersome to run for the entire county and the hurricane model is not germane to Louisville Metro. The earthquake model was used for Louisville Metro in the 2005 Plan and was again used for the five-year update to determine loss estimates for Earthquake using local soil data improvements.

Key Definitions for the Louisville Metro Vulnerability Assessment Model:

- *Hazard Identification:* A hazard is considered to be anything which either threatens the residents of a community or the things that they value.
- *Exposure:* Our Community's assets - People, Property, Essential Facilities, and Infrastructure potentially exposed to a hazard.
- *Risk:* Risk equals our hazard probability based on occurrences and or our probability based on geographic hazard layers.
- *Vulnerability:* Defines what part of our "exposure" is at "risk" to each "hazard".

GIS staff spent many hours of research and conducted test runs to develop its updated methodology. The final model relies heavily on GIS spatial analyses and provides the user with several layers of integrated information which can also be used individually to display different planning scenarios. To facilitate data collection and analysis, the census block boundaries were used to organize the data inputs. This approach enabled the creation of a vulnerability score for each census block and for each hazard and thus creating a very refined vulnerability assessment.

3.2.3.2 Model

The Hazard Vulnerability Score provides a visual display of the potential extent each hazard poses on the community. The vulnerability scores are displayed at the Census Block level which provides an enhanced local assessment displaying where risk and vulnerabilities are located.

HAZARD VULNERABILITY SCORE *= Exposure Score X Risk Score*

3.2.3.3 Definitions of Variables to Determine Exposure Score

The Louisville Metro Exposure Score is comprised of the following nine variables.

EXPOSURE SCORE *= Population Rank + Property Rank + Essential Facilities Rank + Utilities Rank + Transportation Rank + Government Facilities Rank + Civic/Employment Center Rank + Dam/Levee Rank + Hazardous Materials Rank*

The following define the variables used to determine an Exposure Score.

Population Rank – Derived from the total number of population per each census block and a vulnerable population count created through a census tract analysis based on key social economical indicators that was aggregated to the blocks. This data was captured using 2000 Census data.

Property Rank – Derived from combining the total number of primary buildings and the building or improvement value per each census block. This data was captured using LOJIC and Jefferson County PVA data.

Essential Facilities Rank – Derived from combining the total number of essential facilities located within each census block. Data collected from Louisville Metro databases, Emergency Operations Plan (EOP), Jefferson County Public Schools (JCPS), LOJIC, Louisville Water Co., Louisville Metro EMA, Louisville Metro and Suburban Fire Districts, Louisville & Jefferson County Metropolitan Sewer District (MSD), and state databases.

Exposure Model Contains

- Civic/Employment Centers
- Dams and Levees
- Essential Facilities
- Government Facilities
- Hazardous Materials Facilities
- Population
- Property
- Transportation
- Utilities
- Composite Exposure

The Essential Facilities Rank includes: Police/Fire/EMS, hospitals/emergency care, nursing homes, day cares, schools/colleges, jails, military, media, emergency telecoms, emergency operations centers (EOCs), and shelters.

Utility Facilities Rank – Derived from combining the total numbers of utility infrastructure located within each census block. Data collected from Louisville Metro databases, Louisville Water Co, LOJIC and state databases. Utility Facilities Rank includes: water stations, wastewater stations, wastewater pump stations, drainage, Louisville Gas & Electric (LG&E) facilities (electric and gas), and cell towers.

Transportation Rank – Derived from combining the total numbers of transportation infrastructure located within each census block. Data collected from Louisville Metro databases, LOJIC, and state databases. Transportation Rank includes: airports, bus stations, highway bridges/tunnels, ports, railroad track footage, and road footage.

Government Facilities Rank – Derived from combining the total number of local, state, and federally owned facilities located within each census block. Data collected from Louisville Metro databases, LOJIC and by geo-locating structures

Civic/Employment Center Rank – Derived from combining the total number of civic and employment centers located within each census block. Data collected from LOJIC, Louisville Metro Economic Development, *Business First*, and Louisville Metro Databases. Civic/Employment Center Rank includes: Manufacturing/industrial/office/service centers, shopping centers, hotels/motels, convention/meeting, museums, sports venues, theatres, religious facilities, and grocers.

Dam/Levee Rank – Derived from combining the total number of dams and levees located within each census block. Data collected from Kentucky Division of Water (KDOW), Corp of Engineers, LOJIC, Louisville Metro databases, and state databases. Dam/Levee Rank includes: State/local regulated dams, Corp of Engineer Dams, and local levees.

Hazardous Materials Rank – Derived from combining the total number of hazardous materials/facilities located within each census block. Hazardous Materials Rank includes locations where Hazardous Materials are stored and includes facilities housing industrial/hazardous materials, such as corrosives, explosives, flammable materials, radioactive materials, and toxins. Data was collected from Louisville Metro EMA, MSD, LG&E, and LOJIC.

The Exposure Score places the asset variables into the Hazard Vulnerability Score. Each variable was calculated and then ranked 0 to 3 (0 = No data, 1 = Moderate, 2 = High, and 3 = Severe), using the Natural Breaks (Jenks) method provided in ArcGIS as a classification choice. Next, the ranks were added to produce a composite Exposure Score, one of the variables used to equate the Hazard Vulnerability Score. Please see Appendix 3.1 for a visual representation of each Exposure Score variable.

3.2.3.4 Definitions of the Risk Score

The second variable created for the Vulnerability Score is the Risk Score.

RISK SCORE = *Occurrence Rank and/or Area Affected Rank*

Each hazards Risk Score varies depending on the best available data.

Occurrence Rank - based on the number of hazard occurrences within an individual planning area (Census Blocks). Specific areas with high occurrences are identified as being at Risk based on occurrences and probability.

Area Affected Rank - developed using Hazard Zone maps. For example, the flood hazard provides a Flood Zone from the Digital Flood Insurance Rate Map (DFIRM) which can be used to geographically represent areas of high risk. These Hazard Zones are overlaid on the planning areas and weighted based on the percent of area the Hazard Zone covers within each planning area or census block.

Some hazards have both variables while others have only the Occurrence Rank or Area Affected Rank. The individual Risk Score for each hazard will be described within the Assessing Vulnerability section of each hazard.

The Risk Score assigns a hazard/risk variable to the Hazard Vulnerability Score. The Risk Score varies with each hazard due to the fact some hazards have area boundaries for analysis, like flooding, while numbers of occurrences are best for those hazards occurring anytime or anyplace, like severe storms. An *Occurrence Rank* was created for each hazard where data permitted and was added to the hazards *Area Affected Rank* where data permitted to create Hazard Risk Score. Each variable was calculated and then ranked 0 to 3 (0 = No data, 1 = Moderate, 2 = High, and 3 = Severe), using the Natural Breaks (Jenks) method provided in ArcGIS as a classification choice.

It is important to note that the Risk Score is developed based on the representation of a hazard affecting an area, either based on past occurrence or a scientifically based study (i.e. flood study DFIRM). This makes the Risk Score particularly useful for land use planning and future development decisions. The Vulnerability Score adds current assets (Exposure Score) to the model which is vital when dealing with emergency management planning issues. This is pointed out to display the multiple uses of the data created during this process.

After the Exposure Score and the Risk Score were determined, the equation was set into motion to produce a Hazard Vulnerability Score for each identified hazard. The Hazard Vulnerability Scores contain some bias toward the more populated areas in the county. This is due to a correlation between more populated areas and a tendency to have higher numbers of essential facilities, properties, transportation facilities (Exposure Variables). This resulted in higher populated areas having greater exposure in general. However, with the data provided, other equations can be developed with or without one or more variables, or a different weighting system. The goal of this model was to assess the most vulnerable areas throughout Louisville Metro. Given the most populated areas have the most at risk, this model achieved that goal.

Also of note is the extent ranking was changed for the updated Plan in order to focus emphasis on each ranking (1 moved from Low to Moderate, 2 moved from Medium to High, and 3 moved from High to Severe). The extent ranks provide the viewer a relative scale for understanding the level of risk each hazard poses in a particular planning area

Future Data Collection

The 2010 Kentucky State Hazard Mitigation Plan, submitted to FEMA for approval, proposes a new system to collect data through a statewide portal known as The Commonwealth Hazard Assessment and Mitigation Planning System CHAMPs. With the implementation of state's CHAMPS system, data collection capture will occur at the local level using a form of HAZUS-MH's Comprehensive Data Management System which provides users with the capability to update and manage statewide and local datasets that are currently used to support risk and vulnerability analysis. Louisville Metro will support this effort during the next Plan Update.

3.2.4 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses

As outlined in FEMA's review in the Louisville Metro Crosswalk, the 2005 Plan was deficient as a result of 'unmet' categories in the Assessing Vulnerability sections of the Risk Assessment. The comprehensive plan update addresses these deficiencies and assists with Identifying Structures, Estimating Potential Losses, and Analyzing Development Trends.

Specifically, better data allows Louisville Metro to describe vulnerability in terms of types and numbers of future buildings, infrastructure and critical facilities, and to estimate the potential dollar losses to all vulnerable structures in relation to all hazards. Improved understanding of risk and vulnerabilities also improves the mitigation strategy. Enhancement of data enhances the quality of locating mitigation needs. Louisville Metro will continue to pursue methods to enhance the Risk Assessment data in the future.

In order to Identify Structures that are vulnerable to each identified hazard the Project Staff used the Hazard Boundary Overlay methodology. The Hazard Boundary Overlay model is a geospatial function of identifying structures located within the Hazard Boundary layers. For example a flood hazard boundary (DFIRM) would be overlaid onto a building point layer; the buildings located within the DFIRM layer would be identified using GIS spatial analysis.

Some hazards have mapped hazard boundaries that were used to develop the *Area Affected Ranks.* Other hazards may not have the mapped scientific boundary layers but do have mapped Severe (3) ranked *Hazard Vulnerability Score* areas. For the hazards that did not have a mapped Hazard Boundary layer the Severe (3) census blocks were used as the hazard boundary for overlay onto the PVA's GIS building data points. This methodology allowed the Project Staff to identify structures for ten of the hazards (Dam/Levee Failure, Earthquake, Flood, HAZ/MAT, Hail, Karst/Sinkhole, Landslide, Severe Storm, Tornado, and Wildfire). Currently there is not sufficient data to identify structures vulnerable to Drought, Extreme Heat, and Severe Winter Storms so all structures are considered equally vulnerable.

A further detailed description of the methodology used for each hazard will be provided under each Hazard section.

3.2.4.1 Loss Estimation Methodologies

Estimating losses is essential to decision-making at all levels of government, providing a basis for developing mitigation plans and policies, emergency preparedness, and response and recovery planning. Nationally, there are several methodologies in place to answer the question of "Estimating Potential Losses". Uncertainties are inherent in any loss estimation methodology, arising in part from incomplete scientific knowledge concerning natural hazards and their affects on the built environment as well as incomplete and varied damage inventories.

Project Staff used best available data from a variety of national and local damage estimate inventories for each hazard (NCDC, FEMA, State, and Local). Uncertainties also result from approximations and simplifications which are necessary for a comprehensive analysis (such as incomplete inventories, demographics, or economic parameters).

3.2.4.2 Hazard Boundary Overlay Loss Estimate Model

This model uses the same methodology as mentioned above with Identifying Structures that are vulnerable. The Hazard Boundary Overlay model is a geospatial function of identifying structures located within the Hazard Boundary layers. As mentioned, this methodology is the exact one used in identifying structures that are vulnerable - with the addition of adding dollar values and potential losses to the structures identified within each hazard zone. For example a flood hazard boundary (DFIRM) would be overlaid onto a building layer; the structures located within the DFIRM layer would be identified using GIS spatial analysis. The next step is to add value to those structures identified as being vulnerable. The Project Staff used local PVA data to develop a comprehensive data set of structures and replacement costs for Louisville Metro. The structures located within the hazard layers were identified and designated as vulnerable and then estimated to be damaged during an event.

Some hazards have mapped hazard boundaries that were used to develop the *Area Affected Ranks.* Other hazards do not have the mapped scientific boundary layers but do have mapped (3) Severe Ranked *Hazard Vulnerability Score* areas.

- For the hazards that did not have a mapped Hazard Boundary layer the Severe (3) census blocks were used as the hazard boundary for overlay onto the PVA's GIS building data points. This methodology allowed the Project Staff to identify vulnerable structures and estimate potential losses for the following ten hazards: Dam/Levee Failure, Earthquake, Flood, HAZ/MAT, Hail, Karst, Landslide, Severe Storm, Tornado, and Wildfire.
- Currently there is not sufficient data to estimate potential losses on structures for three hazards: Drought, Extreme Heat, and Severe Winter Storms. As a result, all structures are considered equally vulnerable.

This methodology reflects potential losses based on where the hazards have been located via Hazard Boundary maps or the (3) Severe Vulnerability Score layers in correlation with the built environment. This model reflects the Hazard Vulnerability Score model but adds potential damage to the equation. The model typically over estimates the annual potential damage but does provide the reader an understanding of where mitigation projects should occur based on high exposure in correlation with high risk.

3.2.4.3 Average Annualized Loss Estimate Model

In order to determine the Average Annualized Loss for a hazard, Project Staff reviewed the probability and the past consequences. The following is the model:

Average Annualized Loss *= Probability x Consequences*

Probability is based on past occurrences and consequences are based on past losses. For purposes of this plan, the probability of a future event occurring in any given year is calculated based upon the number of past events divided by the number of years of record. For example, if there have been 47 severe winter storms throughout the county over the last 50 years, there is an annual occurrence ratio of 0.94 (probability). Next, the average consequences of each event are calculated by dividing the total losses ($3,134,033) by the frequency (47) of the event, giving an Average Consequence of $66,682.

Knowing both the "annual occurrence probability ratio" and the "average consequences per occurrence" produces the ability to predict an Average Annualized Loss for any given year by multiplying the two values together. Therefore, for any given year, it is likely that somewhere in the county, approximately $62,681 worth of damages will be sustained from a Severe Winter Storm.

Project Staff used sufficient data to develop an Average Annualized Loss estimate on the following seven hazards: Extreme Heat, Flood, Hail, Landslide, Severe Storm, Severe Winter Storm, and Tornado. The following table represents these estimates.

Hazard Type	Start Range	End Range	Range	Frequency	Total Losses	Probability	Average Consequences	Average Annualized Loss
Dam Failure	0	0	0	0	$0	0.00	$0	$0
Flooding	1964	2010	46	41	$208,298,243	0.89	$5,080,445	$4.528.223
Severe Storm	1957	2010	53	169	$15,123,690	3.19	$89,489	$285,353
Severe Winter Storm	1960	2010	50	47	$11,623,778	0.94	$247,314	$232,476
Tornado	1960	2010	50	14	$15,000,384	0.28	$1,071,456	$300,008
HAZ/MAT	1986	2010	24	999	$0	41.63	$0	$0
Hail	1961	2010	49	46	$27,884,579	0.94	$606,187	$569,073
Karst/Sinkhole *	0	0	0	451 *	$0	0.00	$0	$0
Drought	1895	2010	115	29	$0	0.25	$0	$0
Earthquake	0	0	0	0	$0	0.00	$0	$0
Extreme Heat	1983	2010	27	11	$9,027	0.41	$821	$334
Landslide	1990	2010	20	7	$98,851	0.35	$14,122	$4,943
Wildfire	2000	2010	10	4	$0	0.40	$0	$0
TOTALS					**$278,038,552**		**$7,109,834**	**$1,392,191.751**

** Note these are sinkhole occurrences*

This methodology creates a loss estimate based on actual past events and losses from those events. The Average Annualized Loss estimate model does not specify where in the county these events can occur but does allow an understanding of which hazards have caused the most damages over a specified time frame. This data is key in reviewing which hazards should be addressed in the Mitigation Strategy section.

Per the Louisville Metro EOP, the following is the Projected Impact Potential.

HAZARD CATEGORY	*Projected Impact Potential*																	
	Excessive wind	Excessive water	Damaging hail	Electric power outage	Surface and air transportation disruption	Navigable waterway impairment	Potable water system loss of disruption	Sewer system outage	Telecommunications system outage	Human health and safety	Psychological hardship	Economic disruption	Disruption of community services	Damage to critical environmental resources	Damage to identified historical resources	Fire	Toxic releases	Stormwater draining impairment
NATURAL																		
Flood	▲	▲		▲	▲	▲	▲	▲		▲	▲	▲	▲	▲	▲	▲	▲	▲
Tornado	▲		▲	▲	▲				▲	▲	▲	▲						
Severe Weather	▲	▲	▲	▲	▲				▲	▲	▲	▲						
Winter Storm (ice and snow)				▲	▲	▲			▲	▲	▲	▲	▲					
Earthquake				▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
TECHNOLOGICAL																		
Hazardous material release					▲	▲				▲	▲	▲		▲		▲	▲	
Communications failure									▲	▲		▲	▲					
Transportation system accident					▲	▲				▲		▲	▲					
Energy/power failure				▲	▲		▲	▲	▲	▲	▲	▲	▲					
SOCIETAL																		
Civil disturbance					▲					▲	▲	▲	▲		▲			
Terrorism and sabotage				▲	▲	▲	▲		▲	▲	▲	▲	▲	▲	▲	▲	▲	

LM EOP 2009 – 10

3.3 Dam / Levee Failure

Description: Kentucky statute KRS 150.100 defines a dam as any artificial barrier including appurtenant works that do, or can, impound or divert water and:

- Is 25 feet or more high from the natural bed of the stream or watercourse at the downstream toe of the barrier, as determined by the Natural Resources and Environmental Protection Cabinet;
- Has or will have an impounding capacity of 50 acre feet or more at the maximum water storage elevation.

In the U. S.

Currently, there are about 2,000 "unsafe" dams in the U.S. There are unsafe dams in almost every state. A majority of states and federal agencies define an "unsafe" dam as one that has been found to have deficiencies that leave it more susceptible to failure.

There are about 80,000 dams in the U. S., the majority of which are privately owned. Other owners are state and local authorities, public utilities, and federal agencies. The benefits of dams are numerous; they provide water for drinking, navigation, and agricultural irrigation. Dams also provide hydroelectric power and create lakes for fishing and recreation. Most important; dams save lives by preventing/reducing floods.

If dams have many benefits, they can also pose a risk to communities if not designed, operated, and maintained properly. In the event of a dam failure, the energy of the water stored behind even a small dam is capable of causing loss of life and great property damage if there are people downstream of the dam. Historically, dams that failed had some deficiency, as characterized above, which caused the failure. These dams are typically termed "unsafe". The National Dam Safety Program is dedicated to protecting the lives of American citizens and property from the risks associated with the development, operation, and maintenance of America's dams.

Dam and Levee Failure Flooding are potentially the worst flood events. A dam failure is usually the result of neglect, poor design, or structural damage caused by a major event such as an earthquake. When a dam fails, an excess amount of water is suddenly let loose downstream, destroying anything in its path. Many dams and levees are built for flood protection. They usually are engineered to withstand a flood with a computed risk of occurrence. For example, a dam or levee may be designed to contain a flood at a location on a stream that has a certain probability of occurring in any one year. If a larger flood occurs, then that structure may be overtopped. If during the overtopping the dam or levee fails or is washed out, the water behind it is released and becomes a flash flood. Failed dams or levees can create floods that are catastrophic to life and property because of the tremendous energy of the released water.

Dam Types

Manmade dams may be classified by:

1) The type of materials used
2) The methods used in construction

3) The slope or cross-section of the dam
4) The way the dam resists water pressure forces
5) The means for controlling seepage
6) The purpose of the dam

Materials used for dams may include earth, rock, tailings from mining or milling, concrete, masonry, steel, timber, and/or miscellaneous materials (such as plastic or rubber).

- *Embankment dams* are the most common type of dam in use today. Materials include natural soil or rock, or waste materials obtained from mining or milling operations. An embankment dam is termed an “earth-fill” or “rock-fill” dam depending on whether it is comprised of compacted earth or of dumped rock. The ability of an embankment dam to resist the reservoir water pressure is primarily a result of the mass weight, type and strength of the materials from which the dam is made.
- *Concrete dams* may be categorized as gravity or arch dams according to the design used to resist the stress of reservoir water pressure. Concrete gravity dams use the mass weight of concrete and friction to resist reservoir water pressure. A buttress dam is a specific type of gravity dam in which the large mass of concrete is reduced, and the forces are diverted to the dam foundation through vertical or sloping buttresses.
- *Concrete arch dams* are typically thin in cross-section. The reservoir water forces acting on an arch dam are carried laterally into the abutments. The shape of the arch may resemble a segment of a circle or an ellipse, and the arch may be curved in the vertical plane as well. Such dams are usually constructed of a series of thin vertical layers that are keyed together; barriers to stop water from flowing are provided between layers.
- *Coal impoundments* are defined by the Mining Safety and Health Administration (MSHA) as any structure associated with coal mining operations built to impound water and, are either at least 20 feet high, or capable of impounding at least 20 acre feet of water. Coal impoundments store coal slurry (wastewater and impurities that result from coal washing and processing). A bulkhead or embankment is made of coarse coal refuse and acts as a dam. Behind it lies a pond of coal slurry. Sediment settles out of this turbid mixture, filling the pond, while wastewater is recycled back into the coal washing process. The sizes of the ponds and bulkheads vary, but pond basins are often hundreds of feet deep and hold millions of gallons of slurry. As of this year, coal impoundment failures have resulted in property damage, environmental contamination and, in one case, loss of life.

Likelihood of Occurrence: Signs of Potential Dam Failure

- *Seepage.* The appearance of seepage on the downstream slope, abutments, or downstream area is cause for concern. If the water is muddy and is coming from a well-defined hole, material is probably being eroded from inside the embankment and a potentially dangerous situation can develop.
- *Erosion.* Erosion on the dam and spillway is one of the most evident signs of danger. The size of erosion channels and gullies can increase greatly with slight amounts of rainfall.

- *Cracks.* Cracks are of two types: transverse and longitudinal. Transverse cracks appear perpendicular to the axis of the dam and indicate settlement of the dam. Longitudinal cracks run parallel to the axis of the dam and may be the signal for a slide, or slump, on either face of the dam.
- *Slides and Slumps.* A massive slide can mean catastrophic failure of the dam. Slides occur for many reasons and an occurrence can mean a major reconstruction effort.
- *Subsidence.* Subsidence is the vertical movement of the foundation materials due to failure of consolidation. Rate of subsidence may be so slow that it can go unnoticed without proper inspection. Foundation settlement is the result of placing the dam and reservoir on an area lacking suitable strength, or over collapsed caves or mines.
- *Structural.* Conduit separations or ruptures can result in water leaking into the embankment and subsequent weakening of the dam. Pipe collapse can result in hydraulic failures due to diminished capacity.
- *Vegetation.* A prominent danger signal is the appearance of "wet environment" types of vegetation such as cattails, reeds, mosses and other wet area vegetation, which can be a sign of seepage.
- *Boils.* Boils indicate seepage water exiting under some pressure and typically occur in areas downstream of the dam.


July 24, 2010, Iowa: Maquoketa River water gushes out of the Delhi Dam as areas surrounding the Maquoketa River. The 200-foot breach in the dam began with a section of two-lane road collapsing.

- *Animal Burrows.* Animal burrows are a potential danger since such activity can undermine the structural integrity of the dam.
- *Debris.* Debris on dams and spillways can reduce the function of spillways, damage structures and valves, and destroy vegetative cover.

Dams are classified based on the evaluation of damage possible downstream. The FEMA guide to dam classifications uses the following system:

CLASSIFICATION OF DAMS	
Classification	**Description**
Class A (Low)	No loss of human life is expected and damage will only occur to the dam owner's property
Class B (Moderate/Significant)	Loss of human life is not probable, but economic loss, environmental damage, and/or disruption of lifeline facilities can be expected
Class C (High)	Loss of one or more human life is expected

(Source: FEMA 333; Federal Guidelines for Dam Safety, Hazard Potential Classifications for Dams, October 1998)

For 30 years, the Federal Government has been working to protect Americans from dam failure through the National Dam Safety Program (NDSP). The NDSP, which is led by FEMA, is a partnership of the states, federal agencies, and other stakeholders to encourage individual and community responsibility for dam safety.

National Performance of Dams Program Dam Facts

- 76,926 dams listed in the national inventory *(1998-1999 edition)*
- 2.7% of the dams are owned by the federal government
- 81% of the dams in the inventory are earthen dams
- 1,595 significant hazard dams are within one mile of a downstream city
- 20 dams in the inventory were completed in the 18th century
- 569 dams are owned by the U.S. Army Corps of Engineers (USACE)
- 40 years is the average age for a dam

3.3.1 Dam / Levee Failure Profile

SUMMARY OF DAM/LEVEE FAILURE RISK FACTORS

Period of occurrence:	Dam/levee malfunctions and failures can occur at any time during the year, day or night
Number of Events to-date:	0 events Louisville Metro has 41 dams and 1 major levee
Probability of event(s):	0 Infrequent. Dams and levees that fail, historically, have some deficiency, which caused the failure. Chance of failure increases with heavy rain or earthquake.
Warning time:	Minimal, depends on frequency of inspection.
Potential Impact(s):	Impacts human life and public safety. Economic loss, environmental damage, and/or disruption of lifeline facilities. • High Hazard-classified dam failure would cause loss of life, serious damage to homes, industrial or commercial buildings, important utilities, main highways • Moderate Hazard-failure would cause significant damage to property, homes, highways, utilities but no loss of life. • Low Hazard-failure would cause loss of dam, little or no damage to other structures or loss of life.
Past Damages:	No data

Kentucky
Dam Inventory

- 970 dams
- 32 Levee and Floodwall Systems

Background: Since 1948, anyone in Kentucky proposing to construct a dam has been required to submit a plan to the state for review in order to obtain a permit. In 1966, Kentucky adopted a set of guidelines for evaluating dams. In 1974, the permit system was revised to include regular state inspection of dams. KRS 150.295 directs the Secretary of the Natural Resources and Environmental Protection Cabinet to inspect dams and reservoirs on a regular schedule.

The Dam Safety and Security Act of 2002 (Public Law 107-310): signed into law on December 2, 2002, addresses safety and security for dams through the coordination by FEMA of federal programs and initiatives for dams and the transfer of federal best practices in dam security to the states. The Act of 2002 includes resources for the development and maintenance of a national dam safety information network and the development of a strategic plan that establishes goals, priorities, and target dates to improve the safety and security of dams in the U.S.

Historical Impact

Kentucky has approximately 1,000 dams, with almost 200 dams being identified by FEMA as High Hazard – or Class C – dams. Since 1973, there have been 11 dam malfunctions reported to the National Performance Dam Program, seven of those being complete dam failures. There have been no malfunctions or failures in Louisville Metro.

Coal impoundments also pose a severe threat to humans and the environment in the event of failure. According to the MSHA, of the 713 impoundments nationwide, 121 are found in Kentucky and 60 of those are high risk impoundments in terms of retaining failure. (2010 KY Hazard Mitigation Plan).

Types of Dam Failures

- *Hydraulic Failure.* Hydraulic failures result from the uncontrolled flow of water over the dam, around the dam and adjacent to the dam, and the erosive action of water on the dam and its foundation. Earth dams are particularly vulnerable to hydraulic failure since earth erodes at relatively small velocities.
- *Seepage Failure.* All dams exhibit some seepage that must be controlled in velocity and amount. Seepage occurs both through the dam and the foundation. If uncontrolled, seepage can erode material from the foundation of an earth dam to form a conduit through which water can pass. This passing of water often leads to a complete failure of the structure, known as piping.

Dam is overtopping during severe storm in Kentucky
Photo courtesy of KDOW.

- *Structural Failure.* Structural failures involve the rupture of the dam and/or its foundation. This is particularly a hazard for large dams and for dams built of low strength materials such as silts, slag, fly ash, etc. Dam failures generally result from a complex interrelationship of several failure modes. Uncontrolled seepage may weaken the soils and lead to a structural failure. Structural failure may shorten the seepage path and lead to a piping failure. Surface erosion may lead to structural or piping failures.

Potential Damage by Dam Failure: Dam-and Levee-Failure Flooding are potentially the worst flood events. A dam failure is usually the result of neglect, poor design, or structural damage caused by a major event such as an earthquake. When a dam fails, an excess amount of water is suddenly let loose downstream, destroying anything in its path. Many dams and levees are built for flood protection and usually are engineered to withstand a flood with a computed risk of occurrence. For example, a dam or levee may be designed to contain a flood at a location on a stream that has a certain probability of occurring in any one year. If a larger flood occurs, then that structure may be overtopped. If during the overtopping the dam or levee fails or is washed out, the water behind it is released and becomes a flash flood. Failed dams or levees can create floods that are catastrophic to life and property because of the tremendous energy of the released water.

Louisville Metro Dam/Levee Inventory

Following is an inventory of Louisville Metro dams maintained by the U.S. Army Corps of Engineers and the Kentucky Cabinet for Natural Resources and Environmental Protection, Division of Water. The nine Class C dams are at the highest risk and are required to have an emergency action plan, which is maintained by the dam owner.

Louisville Metro Summary of Dams Class A, B & C			
	Class A (Low)	Class B (Moderate)	Class C (High)
STATE	18	13	10
		TOTAL	41*

*Includes McAlpine Dam

The list of Louisville Metro's 40 dams according to the Kentucky Division of Water (KDOW) is as follows.

#	NAME OF DAM	HAZARD CASS	OWNER TYPE	TOPO	HEIGHT	AREA
1.	TOM WALLACE LAKE DAM	(CLASS C) HIGH	MUN	VALLEY STATION	31	2.5
2.	PINE HILL LAKE NO 1	(CLASS C) HIGH	PRI	LOUISVILLE WEST	27	2.8
3.	WINDSOR FOREST DAM	(CLASS C) HIGH	PRI	LOUISVILLE WEST	29	4
4.	MITCHELL HILL LAKE DAM	(CLASS C) HIGH	PRI	VALLEY STATION	20	1.9
5.	LG & E WASTE WATER DAM	(CLASS C) HIGH	PRI	LANESVILLE	12	40
6.	S FORK BEARGRASS CK DRY BED DAM	(CLASS C) HIGH	MUN	JEFFERSONTOWN		13.9
7.	ROBERSON RUN (DRY IMPOUNDMENT)	(CLASS C) HIGH	MUN	LOUISVILLE EAST	17	0
8.	WHIPPS MILL RD DRY DAM	(CLASS C) HIGH	MUN	ANCHORAGE	21	
9.	NORTON COMMONS DAM	(CLASS C) HIGH	PRIV	ANCHORAGE	16	2.4
10.	WATERSTONE PARK DAM	(CLASS B) MODERATE	PRIV	LOUISVILLE EAST	32	
11.	SILVER CRYSTAL DAM	(CLASS B) MODERATE	PRIV	BROOKS	15	10.2
12.	LAKE MCNEELY DAM	(CLASS B) MODERATE	DOFW	BROOKS	32	45
13.	LONG RUN PARK LAKE DAM	(CLASS B) MODERATE	MUN	CRESTWOOD	43	27
14.	BIG HORN LAKE DAM	(CLASS B) MODERATE	PRI	VALLEY STATION	28	3.7
15.	WAVERLY PARK DAM	(CLASS B) MODERATE	PRI	LOUISVILLE WEST	20	4.9
16.	MIRROR LAKE (LOWER) DAM	(CLASS B) MODERATE	PRI	JEFFERSONTOWN	28	3.7
17.	JOE GUY HAGAN DAM	(CLASS B) MODERATE	PRI	JEFFERSONTOWN	28	4.5
18.	LG & E MILL CREEK STATION ASH DAM A	(CLASS B) MODERATE	PRI	KOSMOSDALE	77	56.91
19.	NTS DETENTION DAM SECTION 6B	(CLASS B) MODERATE	PRI	JEFFERSONTOWN	21	4.2
20.	POLO FIELDS	(CLASS B) MODERATE	PRIV	CRESTWOOD	27	13.3
21.	AS PROPERTIES DAM NO 2	(CLASS B) MODERATE	PRIV	JEFFERSONTOWN	24	2

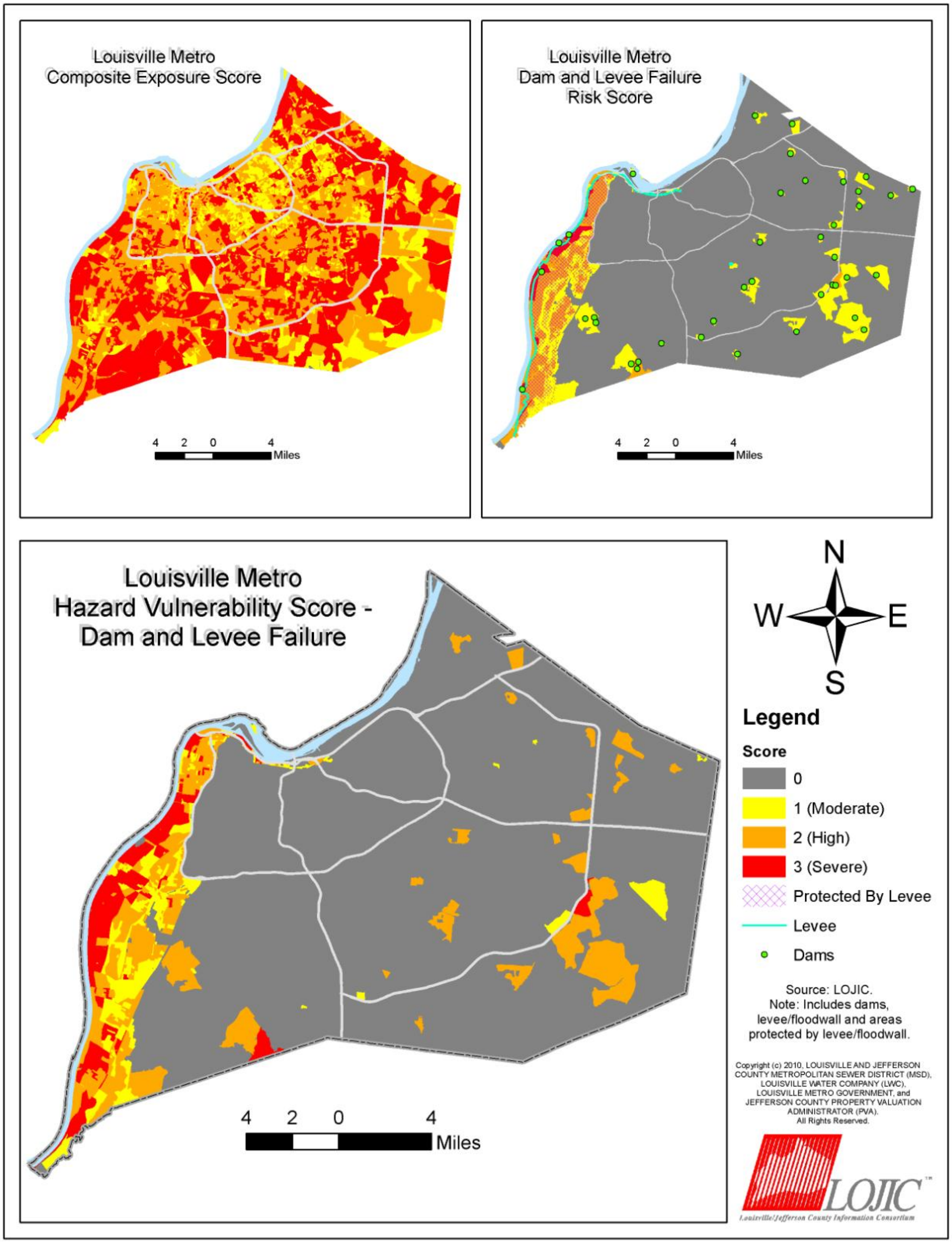
#	NAME OF DAM	HAZARD CASS	OWNER TYPE	TOPO	HEIGHT	AREA
22.	VULCAN QUARRY DAM	(CLASS B) MODERATE	MUN	BROOKS	16	
23.	RIGGS LAKE DAM	(CLASS A) LOW	PRI	JEFFERSONTOWN	18	8.9
24.	FERN CREEK SPORTSMAN CLUB DAM	(CLASS A) LOW	PRI	WATERFORD	25	2.8
25.	DREAMLAND DAM	(CLASS A) LOW	PRI	LOUISVILLE WEST	13	5
26.	WOODHAVEN COUNTRY CLUB DAM	(CLASS A) LOW	PRI	LOUISVILLE EAST	18	4.6
27.	LOWRY DAM	(CLASS A) LOW	PRI	JEFFERSONTOWN	35	2
28.	WILDWOOD COUNTRY CLUB DAM	(CLASS A) LOW	PRI	JEFFERSONTOWN	18	4.6
29.	SAMPSON DAM	(CLASS A) LOW	PRI	FISHERVILLE	40	7.9
30.	WILLOW DAM	(CLASS A) LOW	PRI	ANCHORAGE	33	7.4
31.	PUTNEYS POND	(CLASS A) LOW	PRI	ANCHORAGE	15	7.3
32.	LOGAN LAKE DAM	(CLASS A) LOW	PRI	FISHERVILLE	36	5.8
33.	BILL MCMAHAN LAKE DAM	(CLASS A) LOW	PRI	JEFFERSONTOWN	35	
34.	TWIN LAKES LOWER DAM	(CLASS A) LOW	PRI	FISHERVILLE		
35.	DU PONT FLY ASH	(CLASS A) LOW	PRI	LOUISVILLE WEST	18	20
36.	GLENMARY DAM	(CLASS A) LOW	PRI	MOUNT WASHINGTON	25	4.21
37.	LAKE FOREST GOLF COURSE NO 2	(CLASS A) LOW	PRI	CRESTWOOD	21	6.5
38.	LAKE FOREST GOLF COURSE NO 1	(CLASS A) LOW	PRIV	CRESTWOOD	23	5
39.	SPRINGHURST LAKE DAM	(CLASS A) LOW	PRIV	ANCHORAGE	18	5.7
40.	GAULT EASTPOINT LLC DAM	(CLASS A) LOW	PRIV	ANCHORAGE	20	5.4

Kentucky Division of Water website: http://eppcapps.ky.gov/waterdams/Dams_Query.asp?COUNTY=Jefferson

3.3.1.1 Assessing Vulnerability Overview: Dam/Levee Failure

Dam/Levee Failure Vulnerability Score = Exposure Score X Risk Score

Assessing vulnerability by census block was determined through creating the Dam/Levee Failure Risk Score adding the Occurrence Rank and Area Affected Rank. The Occurrence Rank was determined by first counting and categorizing KDOW dams and USACE Dams within each census block. Each dam was rated as high, medium, and low hazard dams according to KDOW and USACE classifications. A high hazard dam was given a score of 3, medium a score of 2, and low a score of 1. Scores for high, medium, and low hazard dams were then added together to produce a total Dam Risk Score and ranked for each census block 0 to 3 (0 = No data, 1 = Moderate, 2 = High, and 3 = Severe). The Area Affected Rank was determined using the Levee failure inundation map created during the 2006 DFIRM mapping update as the Hazard Boundary and then calculating the percent of the census block affected by the inundation area. The percentage of area affected by the inundation area was then calculated and ranked 0 to 3 (0 = No data, 1 = Moderate, 2 = High, and 3 = Severe). Next, the Dam/Levee Failure Occurrence Rank and Area Affected Rank scores were added together to produce the Dam/Levee Risk Score. The Dam/Levee Failure Vulnerability Score was calculated for each census block by multiplying the census block's Exposure Score by its Dam/Levee Failure Risk Score.


Louisville Metro
Composite Exposure Score
4 2 0 4
Miles
Louisville Metro
Dam and Levee Failure
Risk Score
4 2 0 4
Miles
Louisville Metro
Hazard Vulnerability Score -
Dam and Levee Failure
4 2 0 4
Miles
N
W
E
S
Legend
Score
0
1 (Moderate)
2 (High)
3 (Severe)
Protected By Levee
Levee
Dams
Source: LOJIC.
Note: Includes dams, levee/floodwall and areas protected by levee/floodwall.
Copyright (c) 2010, LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT (MSD), LOUISVILLE WATER COMPANY (LWC), LOUISVILLE METRO GOVERNMENT, and JEFFERSON COUNTY PROPERTY VALUATION ADMINISTRATOR (PVA).
All Rights Reserved.
LOJIC
Louisville/Jefferson County Information Consortium

3.3.1.2 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: Dam/Levee Failure

In order to determine structures that are vulnerable and estimated to be damaged during a Dam/Levee Failure the project staff used the Hazard Boundary Overlay methodology. The Hazard Boundary used as the overlay was the Levee inundation map that was created during the update of the DFIRMs for Louisville Metro. This inundation map displays areas that would be flooded if the Levee was not in place, thus was used to showcase risk in this model.

The following table describes the total number of structures identified within the hazard boundary and the replacement cost of those structures. This model estimates complete damage of each structure located within the Hazard Boundary.

DAM / LEVEE FAILURE	STRUCTURES
COMMERCIAL	2,573
INDUSTRIAL	432
RESIDENTIAL	25,682
OTHER	620
TOTAL BUILDINGS	**29,307**
ESTIMATED LOSS	**$2,394,357,764**

3.4 Drought

Description: A drought is defined as the cumulative deficit of precipitation relative to what is normal for a region over an extended period of time. Unlike other natural hazards, a drought is a non-event that evolves as a prolonged dry spell. Droughts occur when a long period passes without substantial rainfall. A heat wave combined with a drought is a very dangerous situation.

In the U. S.

Droughts can lead to economic losses such as unemployment, decreased land values, and Agro-business losses. In 1998, over 2 billion dollars in property loss was credited to drought in the U. S.

When a drought begins or ends may be difficult to determine. A drought can be short, lasting just a few months, or persist for years before climatic conditions return to normal. While drought conditions can occur at any time throughout the year, the most apparent time is during the summer months. High temperatures, prolonged high winds, and low relative humidity can aggravate drought conditions.

Because the impacts of a drought accumulate slowly at first, a drought may not be recognized until it has become well established. The many aspects of drought reflect its varied impacts on people and the environment. While the impacts of precipitation deficit may be extensive, it is the deficit, not the impacts, that defines a meteorological drought.

Primary Effects

- Crop failure is the most apparent effect of drought in that it has a direct impact on the economy and, in many cases, health (nutrition) of the population that is affected by it. Due to a lack of water and moisture in the soil, many crops will not produce normally or efficiently and, in many cases, may be lost entirely.
- Water shortage is a very serious effect of drought in that the availability of potable water is severely decreased when drought conditions persist. Springs, wells, streams, and reservoirs have been known to run dry due to the decrease in ground water, and, in extreme cases, navigable rivers have become unsafe for navigation as a result of drought.

Secondary Effects

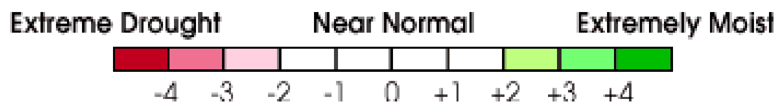
- Fire susceptibility is increased with the absence of moisture associated with a drought. Dry conditions have been known to promote the occurrence of widespread wildfires.

Tertiary Effects

- Environmental degradation in the forms of erosion and ecological damage can be seen in cases of drought. As moisture in topsoil decreases and the ground becomes dryer, the susceptibility to windblown erosion increases. In prolonged drought situations, forest root systems can be damaged and/or destroyed resulting in loss of habitat for certain species. In addition, prolonged drought conditions may result in loss of food sources for certain species.

- In prolonged drought situations the soil surrounding structures subsides, sometimes creating cracks in foundations and separation of foundations from above ground portions of the structure.

The Palmer Drought Severity Index (PDSI) shows the relative dryness or wetness effecting water sensitive economies. The PDSI indicates the prolonged and abnormal moisture deficiency or excess.

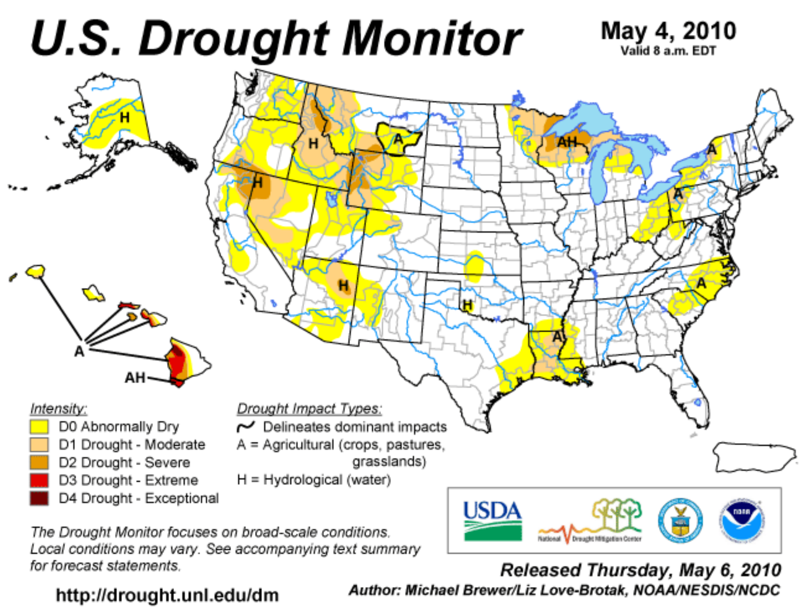


The PDSI is an important climatological tool for evaluating the scope, severity, and frequency of prolonged periods of abnormally dry or wet weather. It can be used to help delineate disaster areas and indicate the availability of irrigation water supplies, reservoir levels, range conditions, amount of stock water, and potential intensity of forest fires.

Climate histories generally begin in 1895. Drought is measured in the PDSI according to the level of recorded precipitation against the average, or normal, amount of precipitation for a region.

Palmer Classifications System (PDSI)	
-2.0 in to -2.99 in	Moderate drought
-3.0 in to -3.99 in	Severe drought
-4.0 in or less	Extreme drought
(Source: National Oceanic and Atmospheric Association (NOAA))	

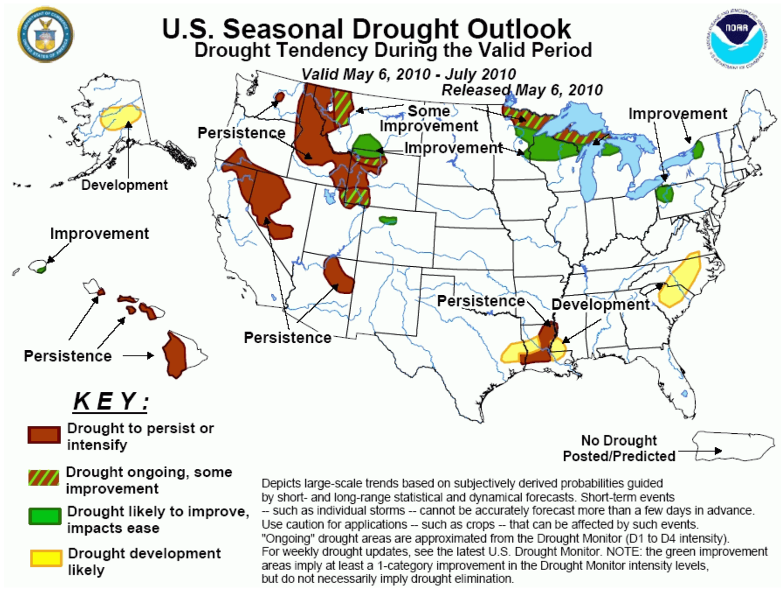
Despite all of the problems that droughts cause, drought has proven to be difficult to define. There is no universally accepted definition because drought, unlike flooding for example, is not a distinct event. Additionally, drought is often the result of many complex factors and has no well-defined start or end. The impacts of drought may again vary by affected sector, thus making definitions of drought specific to particular situations.



The most commonly used drought definitions are based on meteorological, agricultural, hydrological, and socioeconomic effects.

- *Meteorological drought* is defined as a period of substantially diminished precipitation duration or intensity. The commonly used definition of meteorological drought is an interval of time, generally on the order of months or years, during which the actual moisture supply at a given place consistently falls below the climatically appropriate moisture supply.

- *Agricultural droug*ht occurs when there is inadequate soil moisture to meet the needs of a particular crop at a particular time. Agricultural drought usually occurs after or during meteorological drought but before hydrological drought. It can also affect livestock and other dry-land agricultural operations.
- *Hydrological drought* refers to deficiencies in surface and subsurface water supplies. There is usually a delay between lack of rain or snow and less measurable water in streams, lakes, and reservoirs. Therefore, hydrological measurements tend to lag other drought indicators.
- *Socioeconomic drought* occurs when physical water shortages start to affect the health, well-being, and quality of life of the people, or when the drought begins to affect the supply and demand of an economic product.

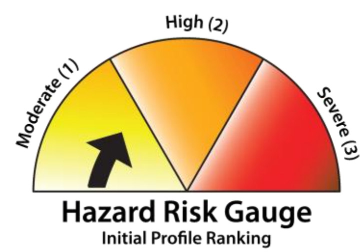


http://www.cpc.ncep.noaa.gov/products/expert_assessment/seasonal_drought.html

3.4.1 Drought Profile

SUMMARY OF DROUGHT RISK FACTORS

Period of occurrence:	Summer months or extended periods of no precipitation.
Number of Events to-date 1895- 2010	29
Probability of event(s):	0.25
Warning time:	Weeks
Potential Impact(s):	Activities that rely heavily on high water usage may be impacted significantly, including agriculture, tourism, wildlife protection, municipal water usage, commerce, recreation, electric power generation, and water quality deterioration. Droughts can lead to economic losses such as unemployment, decreased land values, and Agro-business losses. Minimal risk of damage or cracking to structural foundations, due to soils.
Past Damages:	No data



Kentucky Drought Action Levels

Drought Advisories:

Drought Level I: <u>“Official” recognition of drought</u>

Drought Level II: Serious impacts to human / environment

Drought Level III: Substantial impacts to human / environment

A Level 1 drought indicates moderate drought conditions have developed primarily affecting soil moisture and vegetative health. Serious impacts to agricultural water needs, an increased wildfire risk, water supply shortages with systems on small lakes and reservoirs, and other water-sensitive sectors can be expected in the designated areas.

A Drought Level I declaration will be considered when at least three of the five indicators meet the trigger threshold. At this stage of drought it is expected that some level of drought impact will be observed in one or more drought management regions.

Top Five Droughts in Kentucky

According to the Kentucky Climate Center, the top five drought years in Kentucky are the results of three significant drought episodes.

- 1930-1931
- 1941
- 1953-1954

A Level 2 drought indicates that the Level 1 risks are becoming an actuality. Low stream flows and lower-than-normal lake levels could lead to water conservation advisories and/or mandatory restrictions on water use.

A Drought Level II declaration will be considered when at least three of the five indicators meet the trigger threshold. At this stage of drought it is expected that drought impacts, some severe, will be observed in all of the affected drought management regions including:

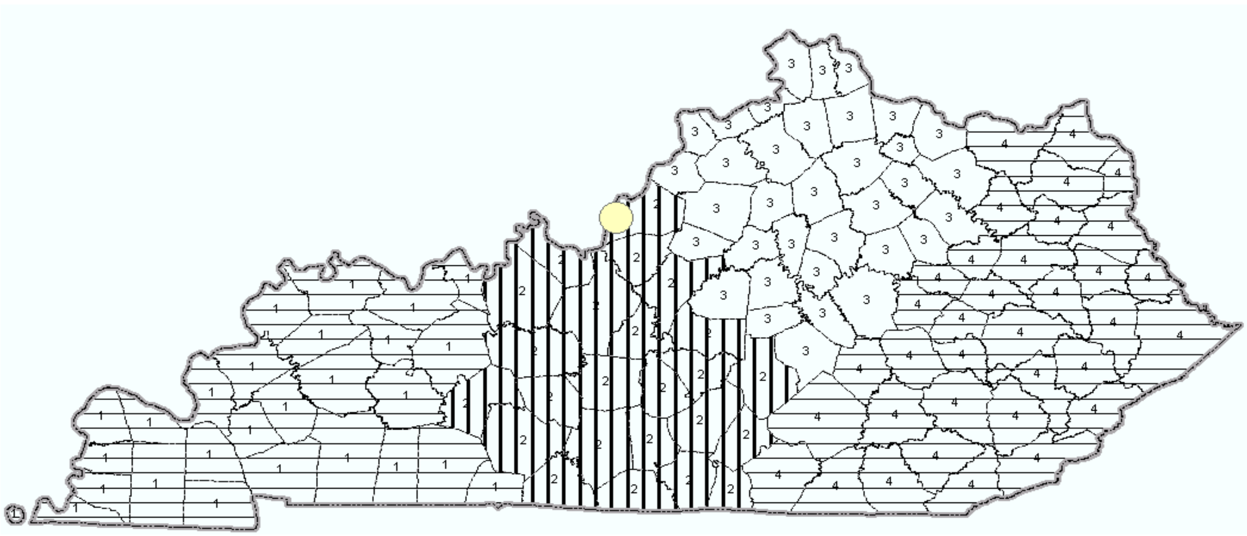
- Moderate to severe impacts to water-sensitive enterprises
- Unusually high demands placed on water treatment facilities
- Depletion of water supplies in shallow wells, springs and small ponds
- Reports of water conservation advisories from communities with drought-vulnerable sources of supply
- Increased incidence wildland and residential fires

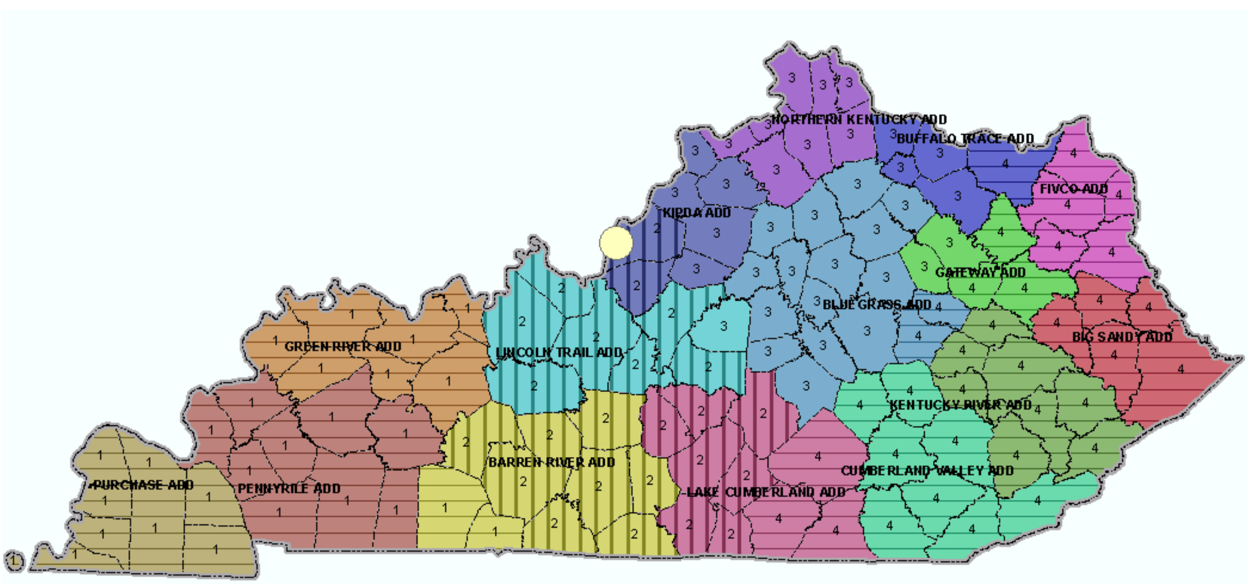
A Drought Level III declaration will be considered when at least three of the five indicators meet the trigger threshold. During this stage of drought it is expected that drought impacts will be widespread and severe and develop into emergencies if drought conditions are not abated, including:

- Severe to extreme impacts to water-sensitive enterprises
- Loss of water supplies in shallow wells, springs and small ponds
- Multiple occurrences of water utilities requiring mandatory water-use restrictions or declaring local water shortage emergencies
- Critical low streamflows impacting water quality and aquatic habitat
- Frequent reports of water utilities having difficulties with adequate treatment for iron or manganese, or with taste and odor problems
- Critically low flows in some major rivers that provide drinking water to large population centers in the drought management regions
- Increased incidence of conflicts between users of diminishing water resources
- Increased incidence wildland and residential fires

Kentucky is divided into four Climatic Divisions for purposes of assessing regional weather and climate conditions. The divisions are separated into Fifteen Drought Management Regions that correspond to the 15 Area Development Districts. These divisions are known as drought management areas (DMAs). Louisville Metro is located in Division 2.

Louisville is highlighted in yellow in the following two maps provided by KDOW.





Louisville Metro Drought History

Research includes: local NWS, EMA, and newspaper archives.

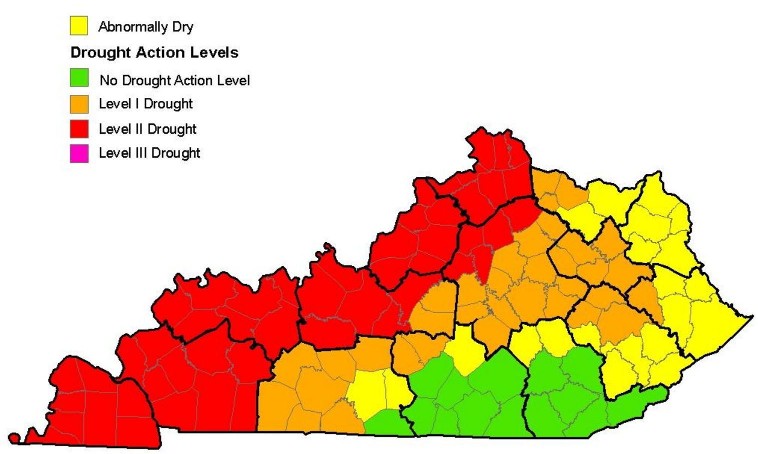
- **August - October 2007** Drought had firmly established itself in the southeastern U.S. by late spring 2007, and began swelling northward during the early summer. By mid-June southern Kentucky had entered a severe drought with precipitation deficits since January 1 on the order of eight inches.

  The severe drought conditions continued to spread northward, and all of central Kentucky felt the effects by the end of June. The Commonwealth issued a Water Shortage Watch for 61 central Kentucky counties. Burn bans went into effect and the Green River Ferry in mammoth Cave National Park discontinued service because of low water levels. A few counties imposed water restrictions on residents. The Tennessee Valley Authority placed a fuel surcharge of $3 to $6 per month per customer on electricity.

  During August, searing heat baked Kentucky, creating significant stress on agricultural concerns and water supplies. Temperatures soaring into the 90s nearly every day and over 100 degrees on several occasions, combined with continued low overall rainfall amounts, locked the region firmly in drought. By the third week of the month roughly the southern half of Kentucky had descended into extreme drought, with severe drought conditions crossing the Ohio River into southern Indiana. People from Logan County to Nelson County to Casey County were about sixteen inches below normal for rainfall since the beginning of the year.

  The number of wildfires in Kentucky increased 500% over the previous summer. In southern Kentucky soil moisture was about half of what it should have been, and 17 counties became eligible for Federal aid. The Barren River at Bowling Green was at its lowest point since the Barren River Dam was erected in 1963.

- **October 2010** A drought declaration was issued for 50 counties in seven DMAs under a Level 2 declaration and 35 counties in eight DMAs under a Level 1 declaration with agricultural disasters and wildfires becoming a major concern. As of October 12, 38 Kentucky counties were under burn bans. See graphic/map for 2010 Drought Action Levels provided by KDOW.



Drought Potential Impacts:

High temperatures, prolonged high winds, and low relative humidity can aggravate drought conditions. In Louisville Metro, a secondary effect of a drought could be low river levels on the Ohio River. Low water can become unsafe for navigation in some areas. As a result, fully loaded barges may not be able to safely navigate the river, and tonnage may have to be reduced by 10 to 20 percent.

Drought can impact the following:

- Agriculture
- Irrigation needs / Livestock needs
- Drinking Water
- Public water supply / Livestock
- Industrial use / Power generation
- Water Quality
- Effluent dominated streams
- Human Health Impacts
- Heat / Airborne particulates
- Environmental Damage
- Erosion / habitat / feed / wildfires
- Structure and Infrastructure
- Water lines / foundations

During periods of drought, some activities that rely heavily on high water usage may be impacted significantly. These activities include agriculture, tourism, wildlife protection, municipal water usage, commerce, recreation, wildlife preservation, electric power generation, and water quality deterioration.

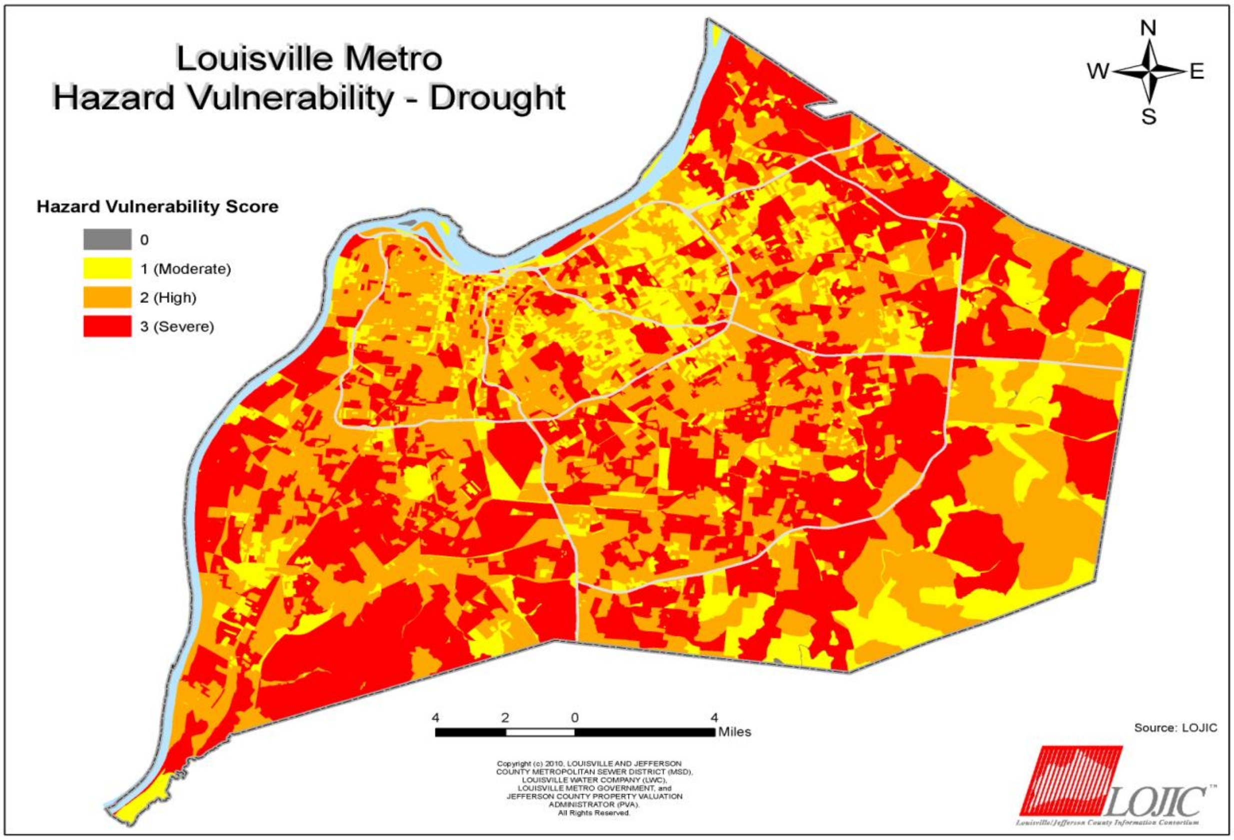
Droughts can lead to economic losses such as unemployment, decreased land values, and Agro-business losses. In addition, there is minimal risk of damage or cracking to structural foundations, due to soils.

3.4.1.1 Assessing Vulnerability Overview: Drought

Drought Vulnerability Score = Exposure Score X Risk Score

The Drought Vulnerability Score is currently difficult to calculate. Currently Louisville Metro has no real spatial data that can be calculated to determine vulnerable areas to drought. Drought is the type of hazard that typically affects a county the size of Louisville Metro equally. With that being said it was determined to use the following Exposure Score map to display the Drought Vulnerability Score based on the assumption that the entire county is equally vulnerable to Drought.

The Exposure Score does provide a visual display of areas that could be harder hit by drought based on the exposure that is within each census block.



3.4.1.2 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: Drought

Identifying structures and estimating potential losses for Drought is very difficult at this time. Without any current spatial data that identifies Drought hazard boundaries, it is assumed that the entire county has equal vulnerability and the potential to be damaged from Drought.

The total number of structures in Louisville is 263,146 with a replacement value of $38,017,288,909.

3.5 Earthquake

Description: An earthquake is a sudden, rapid shaking of the Earth caused by the breaking and shifting of rock beneath the Earth's surface. For hundreds of millions of years, the forces of plate tectonics have shaped the Earth as the huge plates that form the Earth's surface move slowly over, under, and past each other. Sometimes the movement is gradual while at other times, the plates are locked together, unable to release the accumulating energy. When the accumulated energy grows strong enough, the plates break free releasing the stored energy and producing seismic waves generating an earthquake. The areas of greatest tectonic instability occur at the perimeters of the slowly moving plates, as these locations are subjected to the greatest strains from plates traveling in opposite directions and at different speeds. However, some earthquakes occur in the middle of plates.

In the U. S.

Earthquakes strike suddenly and without warning and can occur at any time of the year and at any time of the day or night. On a yearly basis, 70 to 75 damaging earthquakes occur throughout the world. Estimates of losses from a future earthquake in the U. S. approach $200 billion.

There are 45 states and territories in the U. S. at moderate to very high risk from earthquakes.

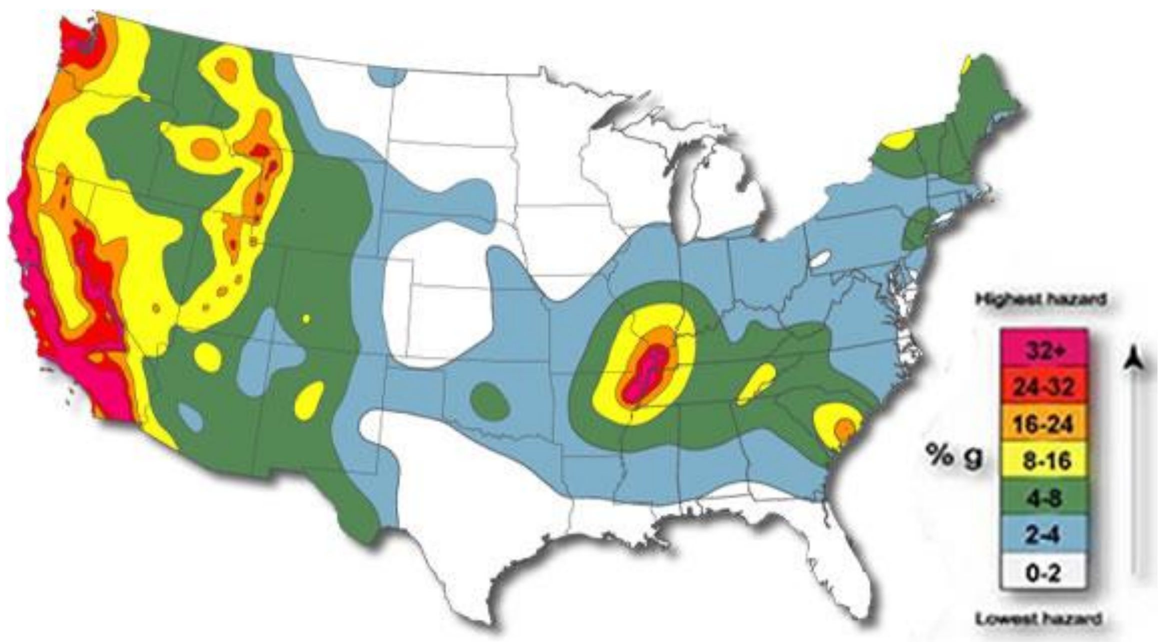
Earthquakes result from crustal strain, volcanism, landslides, or the collapse of caverns. An earthquake is the motion or trembling of the ground produced by sudden displacement of rock in the Earth's crust. Ground motion, the movement of the earth's surface during earthquakes or explosions, is the catalyst for most of the damage during an earthquake. Produced by waves generated by a sudden slip of a fault or sudden pressure at the explosive source, ground motion travels through the earth and along its surface. Ground motions are amplified by soft soils overlying hard bedrock, referred to as ground motion amplification. Ground motion amplification can cause an excess amount of damage during an earthquake, even to sites very far from the epicenter.

Earthquakes can affect hundreds of thousands of square kilometers; cause damage to property measured in the tens of billions of dollars; result in loss of life and injury to hundreds of thousands of persons; and disrupt the social and economic functioning of the affected area. Ground shaking from earthquakes can collapse buildings and bridges, disrupt gas, electric, phone service, and sometimes trigger landslides, avalanches, flash floods, fires, and destructive ocean waves (tsunamis). During an earthquake, buildings with foundations resting on unconsolidated landfill and other unstable soil, and trailers and homes not tied to their foundations are at risk because they can be shaken off their mountings. When an earthquake occurs in a populated area, it may cause deaths, injuries, and extensive property damage.

Most property damage and earthquake-related deaths are caused by the failure and collapse of structures due to ground shaking. The level of damage depends upon the amplitude and duration of the shaking, which are directly related to the earthquake size, distance from the fault site and regional geology. Other damaging earthquake effects include landslides, the down-slope movement of soil and rock (mountain regions and along hillsides), and liquefaction, in which ground soil loses the ability to resist shear and flows much like quick sand. In the case of liquefaction, anything relying on the substrata for support can shift, tilt, rupture, or collapse.

The Northridge, California, earthquake of January 17, 1994, struck a modern urban environment generally designed to withstand the forces of earthquakes. Its economic cost, nevertheless, has been estimated at $20 billion. Fortunately, relatively few lives were lost. Exactly one year later, Kobe, Japan, a densely populated community less prepared for earthquakes than Northridge, was devastated by the most costly earthquake ever to occur. Property losses were projected at $96 billion, and at least 5,378 people were killed. These two earthquakes tested building codes and construction practices, as well as emergency preparedness and response procedures.

California experiences the most frequent damaging earthquakes. However, Alaska experiences the greatest number of large earthquakes-most located in uninhabited areas. The largest earthquakes felt in the U. S. were along the New Madrid Fault in Missouri, where a three-month long series of quakes from 1811 to 1812 included three quakes larger than a magnitude of 8 on the Richter Scale. These earthquakes were felt over the entire eastern U. S., with Missouri, Tennessee, Kentucky, Indiana, Illinois, Ohio, Alabama, Arkansas, and Mississippi experiencing the strongest ground shaking.



Source: U.S. Geological Survey. Earthquake probability map from USGS

Earthquake Types

Earthquakes are measured in terms of their magnitude and intensity. *Magnitude* is measured using the Richter Scale that describes the energy release of an earthquake through a measure of shock wave amplitude. *Intensity* is most commonly measured using the Modified Mercalli Intensity (MMI) Scale.

The Richter magnitude scale measures an earthquake's magnitude using an open-ended logarithmic scale that describes the energy release of an earthquake through a measure of shock wave amplitude. The earthquake's magnitude is expressed in whole numbers and decimal fractions. Each whole number increase in magnitude represents a 10-fold increase in measured wave amplitude, or a release of 32 times more energy than the preceding whole number value.

The Modified Mercalli Scale measures the effect of an earthquake on the Earth's surface. Composed of 12 increasing levels of intensity that range from unnoticeable shaking to catastrophic destruction, the scale is designated by Roman numerals. The roman numerals, with I corresponding to imperceptible (instrumental) events, IV corresponding to moderate (felt by people awake), to XII for catastrophic (total destruction). The lower values of the scale detail the manner in which people feel the earthquake, while the increasing values are based on observed structural damage. The intensity values are assigned after gathering responses to questionnaires administered to postmasters in affected areas in the aftermath of the earthquake.

A detailed description of the Modified Mercalli Scale of Earthquake Intensity and its correspondence to the Richter Scale is given in the table.

Modified Mercalli Intensity Scale for Earthquakes			
Scale	**Intensity**	**Description**	**Corresponding Richter Scale magnitude**
I	Instrumental	Detected only on seismographs	
II	Feeble	Some people feel it	<4.2
III	Slight	Felt by people resting; like a truck rumbling by	
IV	Moderate	Felt by people walking	
V	Slightly Strong	Sleepers awake; church bells ring	<4.8
VI	Strong	Trees sway; suspended objects swing, objects fall off shelves	<5.4
VII	Very Strong	Mild Alarm; walls crack; plaster falls	<6.1
VIII	Destructive	Moving cars uncontrollable; masonry fractures, poorly constructed buildings damaged	
IX	Ruinous	Some houses collapse; ground cracks; pipes break open	<6.9
X	Disastrous	Ground cracks profusely; many buildings destroyed; liquefaction and landslides are widespread	<7.3
XI	Very Disastrous	Most buildings and bridges collapse; roads, railways, pipes and cables destroyed; general triggering of other hazards	<8.1
XII	Catastrophic	Total destruction; trees fall; ground rises and falls in waves	>8.1

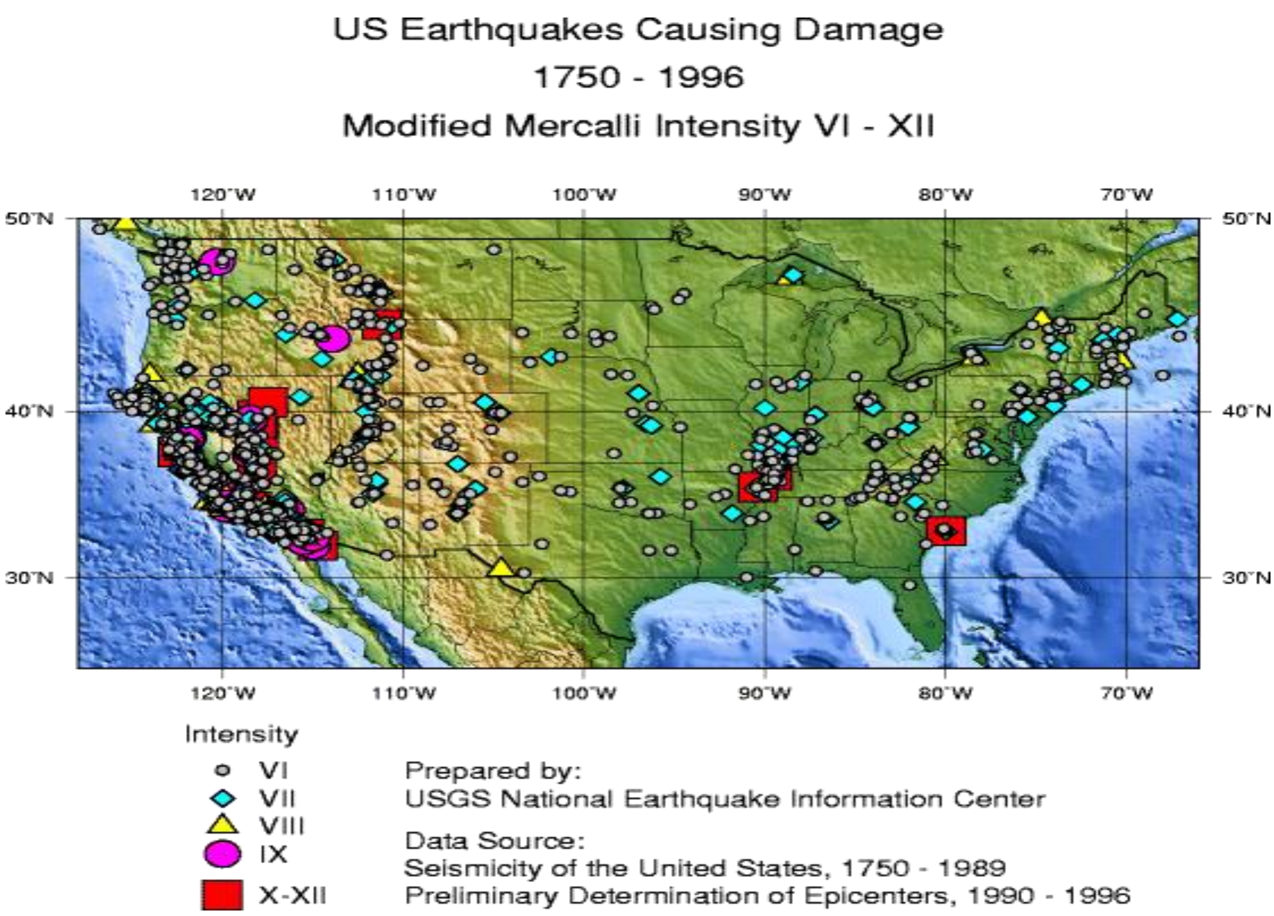
Earthquake Facts

Although earthquakes in the central or eastern U. S. occur less frequently, they effect much larger areas than earthquakes of similar magnitude in the western U. S. For example, the San Francisco, California earthquake of 1906 (magnitude 7.8) was felt 350 miles away in the middle of Nevada, whereas the New Madrid earthquake of December 1811 (magnitude 8.0) rang church bells in Boston, Massachusetts, 1,000 miles away. Differences in geology east and west of the Rocky Mountains cause this strong contrast.

As our existing infrastructure begins to age, the expanding economy and population are forcing new development and construction in more undesirable locations, which are more prone to geologic hazards.

Likelihood of Occurrence

The goal of earthquake prediction is to give warning of potentially damaging earthquakes early enough to allow appropriate response to the disaster, enabling people to minimize loss of life and property. The USGS conducts and supports research on the likelihood of future earthquakes. This research includes field, laboratory, and theoretical investigations of earthquake mechanisms and fault zones.



Source: U.S. Geological Survey. http://earthquake.usgs.gov/earthquakes/states/us_damage_eq.php

A primary goal of earthquake research is to increase the reliability of earthquake probability estimates. Ultimately, scientists would like to be able to specify a high probability for a specific earthquake, on a particular fault, within a particular year. Scientists estimate earthquake probabilities in two ways: by studying the history of large earthquakes in a specific area, and by the rate at which strain accumulates in the rock.

Scientists study the past frequency of large earthquakes in order to determine the future likelihood of similar large shocks. For example, if a region has experienced four magnitude 7 or larger earthquakes during 200 years of recorded history, and if these shocks occurred randomly in time, then scientists would assign a 50 percent probability (that is, just as likely to happen as not to happen) to the occurrence of another magnitude 7 or larger quake in the region during the next 50 years.

But in many places, the assumption of random occurrence with time may not be true, because when strain is released along one part of the fault system, it may actually increase on another part. The two tables below show a comparison of the number of earthquakes for 1990 – 1999 and 2000 – 2010.

Number of Earthquakes in the United States for 1990 - 1999
Located By the USGS National Earthquake Information Center

Magnitude	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
8.0 to 9.9	0	0	0	0	0	0	0	0	0	0
7.0 to 7.9	0	1+1	2	0	1	0	2	0	0	1+1
6.0 to 6.9	2	4	15	9	4	6	4	6	3	6
5.0 to 5.9	64	49	72	62	64	45	100	63	62	50
4.0 to 4.9	284	242	404	270	333	350	612	362	411	352
3.0 to 3.9	626	713	1717	1119	1543	1058	1060	1072	1053	1398
2.0 to 2.9	414	559	998	1009	1196	822	654	759	742	814
1.0 to 1.9	1	3	5	7	2	0	0	2	0	0
0.1 to 0.9	0	0	0	0	0	0	0	0	0	0
No Magnitude	877	599	368	457	444	444	375	575	508	381
Total	2268	2171	3581	2933	3587	2725	2807	2839	2779	3003
Estimated Deaths	0	2	3	2	60	1	0	0	0	0

Red values indicate the earthquakes occurred in Alaska.
Blue values indicate the earthquakes occurred in California.

Number of Earthquakes in the United States for 2000 - 2010
Located By the USGS National Earthquake Information Center

Magnitude	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
8.0 to 9.9	0	0	0	0	0	0	0	0	0	0	0
7.0 to 7.9	0	1	1	2	0	1	0	1	0	0	1
6.0 to 6.9	6	5	4	7	2	4	7	9	9	4	1
5.0 to 5.9	63	41	63	54	25	47	51	72	85	55	31
4.0 to 4.9	281	290	536	541	284	345	346	366	432	293	288
3.0 to 3.9	917	842	1535	1303	1362	1475	1213	1137	1486	1491	1547
2.0 to 2.9	660	646	1228	704	1336	1738	1145	1173	1573	2374	1179
1.0 to 1.9	0	2	2	2	1	2	7	11	13	26	13
0.1 to 0.9	0	0	0	0	0	0	1	0	0	1	0
No Magnitude	415	434	507	333	540	73	13	22	20	16	11
Total	2342	2261	3876	2946	3550	3685	2783	2791	3618	* 4260	* 3071
Estimated Deaths	0	0	0	2	0	0	0	0	0	0	0

* As of 09 July 2010

3.5.1 Earthquake Profile

SUMMARY OF EARTHQUAKE RISK FACTORS

Period of occurrence:	Year-round
Number of Events to-date	0 epicenter occurrences in Louisville Metro. However regional events have affected the area as recently as 2008.
Probability of event(s):	0 epicenter probability Probability of earthquake with M>5.0 within 500 years & 50 km 0.04.
Warning time:	None
Potential Impact(s):	Impacts human life, health, and public safety. Utility damage and outages, infrastructure damage (transportation and communication systems), structural damage, fire, damaged or destroyed critical facilities, and hazardous material releases. Can cause severe transportation problems and make travel extremely dangerous. Aftershocks and secondary events could trigger landslides, releases of hazardous materials, and/or dam and levee failure and flooding.
Past Damages	No data

Background: Specific fault systems in Kentucky include the Rough Creek and Pennyrile Fault Systems, running east-west to the southwest of the Louisville Metro area, and the Cincinnati Arch that runs roughly north-south through Lexington some 75 miles to the east. See map below of Kentucky's fault lines.

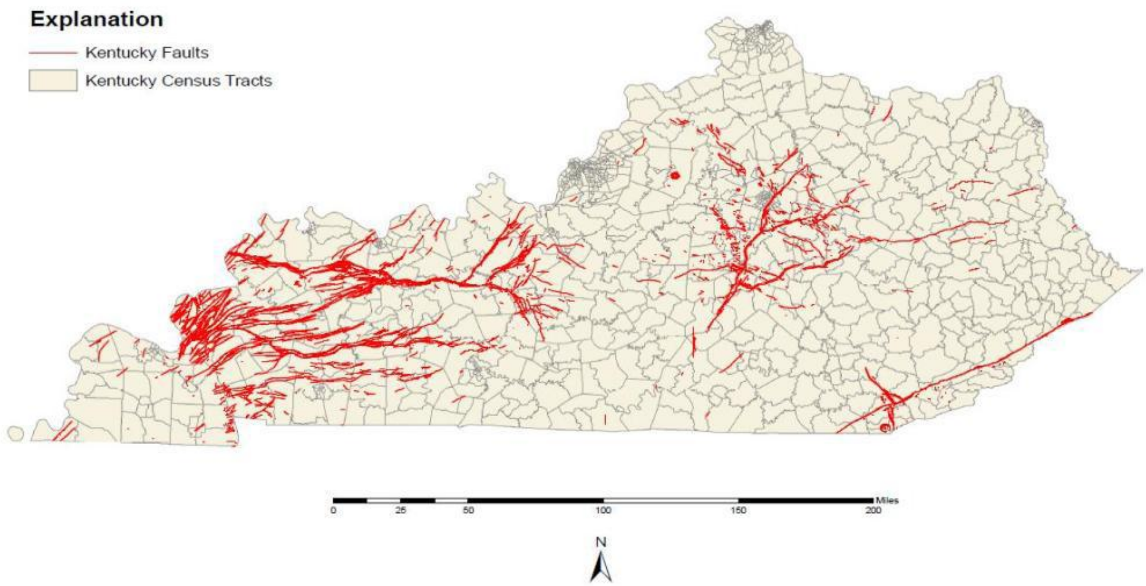
In Kentucky

Earthquakes can be experienced in any part of Kentucky, putting Kentucky's entire population and building stock at risk. Each county has at least one fault running beneath it.

In general, these faults have been inactive for thousands of years. Earthquakes may occur in areas where faults have not yet been identified; this situation presented itself when an earthquake occurred in Sharpsburg in 1980 in an area previously not known to include a fault.

Fault lines run through much of Kentucky, with each of the fifteen area development districts (ADDs) containing at least one fault line or fault system. A number of these systems have remained geologically inactive for significant amounts of time, but others - scientists believe are overdue for a surge in activity.

Kentucky Fault Lines



Source: U.S. Geological Survey. 2008 http://earthquake.usgs.gov/research/hazmaps/products_data/2008/maps/

The three (3) seismic zones most likely to put Kentucky at risk are centered outside of the state, but pose a very real threat to the Commonwealth's citizens.

- *The Eastern Tennessee Seismic Zone* extends from southwest Virginia to northeast Alabama and is one of the most seismically active fault systems in the Southeast. Although the zone has not experienced a large earthquake in historic times, a few minor earthquakes have caused slight damage. The largest recorded earthquake in this seismic zone was a magnitude 4.6 which occurred in 1973 near Knoxville. Sensitive seismographs have recorded hundreds of earthquakes too small to be felt in this seismic zone. Small, non-damaging, felt earthquakes occur about once a year. No evidence for larger prehistoric shocks has been discovered, yet the micro-earthquake data suggest coherent stress accumulation within a large volume. Physical processes for reactivation of basement faults in this region could involve a weak lower crust and increased fluid pressures within the upper to middle crust.
- *The New Madrid Seismic Zone (NMSZ),* located in the central Mississippi Valley, is generally demarked on the north by the confluence of the Ohio and Mississippi Rivers. From this point in southern Illinois, the zone runs southwest, through western Kentucky (near Fulton), through eastern Missouri and western Tennessee and terminates in northeastern Arkansas, crossing the Mississippi River three times.

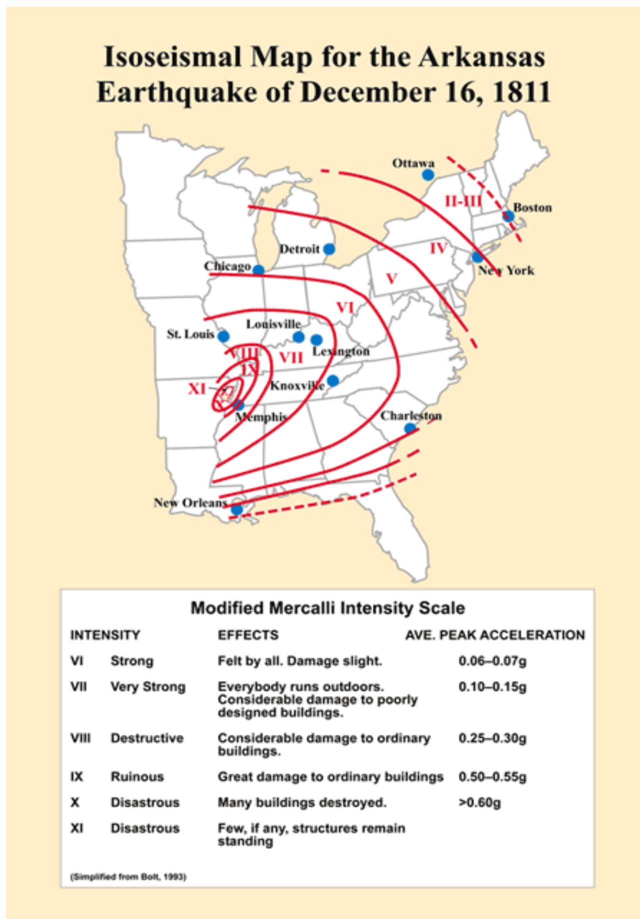
- *The Wabash Valley Seismic Zone* which threatens southern Illinois, Indiana, and Kentucky, shows evidence of large earthquakes in its geologic history. Since 1895, The Wabash Valley Fault Zone has experienced more moderate quakes than the New Madrid Seismic Zone. Some prehistoric quakes which occurred in this zone between 4,000 and 10,000 years ago may have been larger than M6.0. Earthquake ground shaking is amplified by lowland soils, and modern earthquakes of M5.5 to 6.0 in the Wabash Valley Fault Zone could cause substantial damage if they occur close to the populated river towns and cities along the Wabash River and tributaries.

Kentucky Earthquake History

Although there has not been a major earthquake for nearly two hundred years, losses caused by earthquakes in Kentucky have been estimated at about $18.7 million on an annualized basis by FEMA (2001).

Kentucky is affected by earthquakes from several seismic zones in and around the state. The most important one is the New Madrid Seismic Zone, in which at least three great earthquakes, each estimated to have been greater than magnitude 8 on the Richter scale, occurred from December 1811 to February 1812. Though the state was sparsely settled, these great earthquakes affected the whole Commonwealth of Kentucky.

Most of the activity in Kentucky has occurred in the western portion of the State, near the New Madrid seismic zone. The series of catastrophic earthquakes at New Madrid, Missouri, in 1811 - 1812, dominates the seismic history of the middle Mississippi Valley.



Source: Kentucky Geological Survey
http://www.uky.edu/KGS/geologichazards/eqinky.htm

Reports of chimneys being knocked down in many places in Kentucky resulted from the 1811 - 1812 earthquakes at New Madrid, Missouri. A detailed record of 1,874 tremors from the initial shock of December 16, 1811, through March 15, 1812, was kept by Mr. Jared Brooks at Louisville, Kentucky. Shocks continued to occur at frequent intervals for at least two years, thus the total number of shocks was much greater. It is not unlikely that between

2,000 and 3,000 tremors were felt in Kentucky in 1811 and 1812. Reelfoot Lake, a small portion of which extends into Kentucky, is a present-day reminder of the great forces associated with these earthquakes.

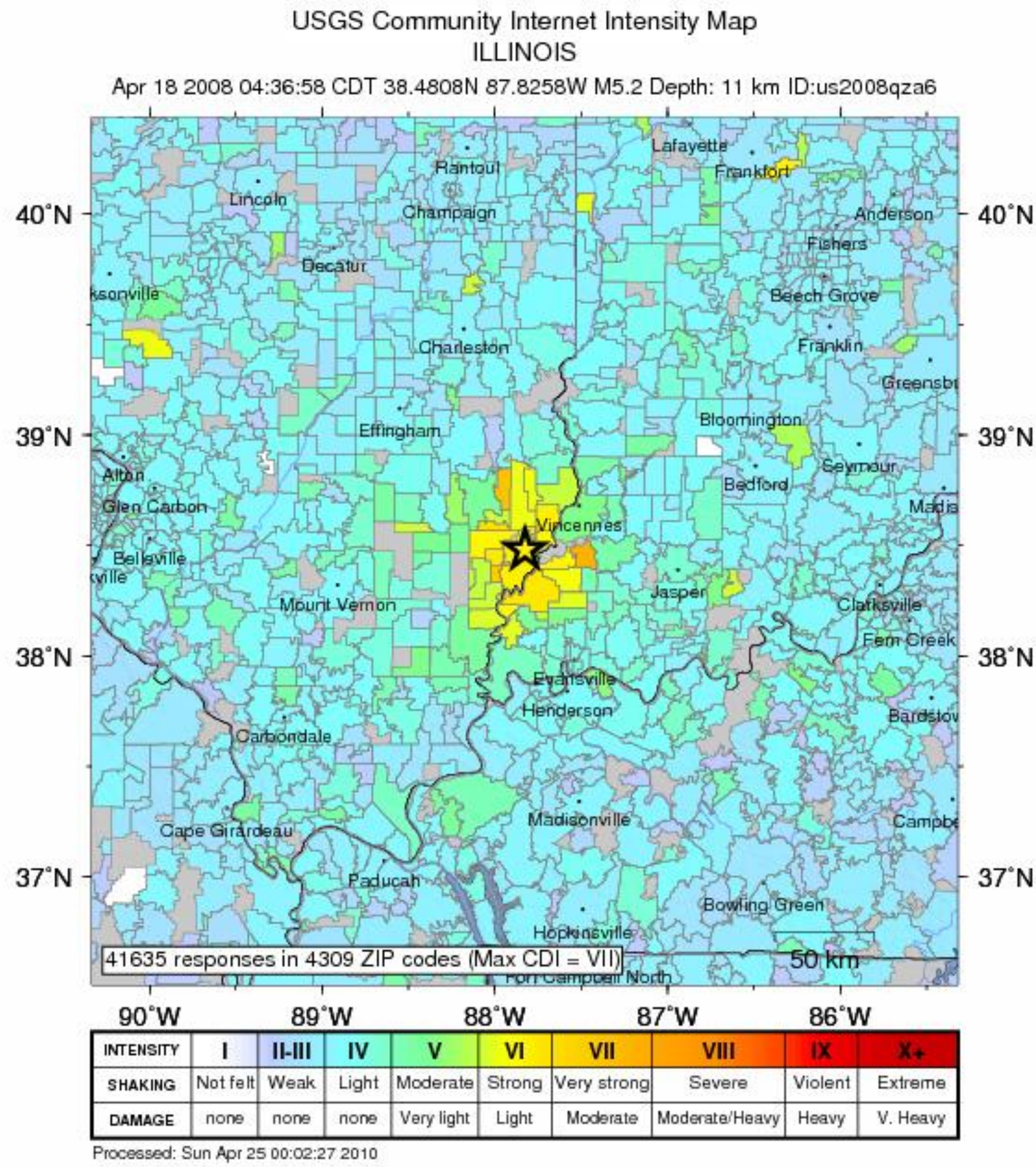
Damage associated with the major earthquakes in 1811 and 1812 was not significant due to the low level of development in the area at the time. However, today over 12.5 million people live in the region impacted by the 1811 to 1812 events. The map shows the Modified Mercalli intensity for the first event of the 1811-1812 New Madrid earthquakes.

The University of Memphis estimates that, for a 50-year period, the probability of a repeat of the New Madrid 1811-1812 earthquakes with:

- A magnitude of 7.5 - 8.0 is 7 to 10%.
- A magnitude of 6.0 or larger is 25 to 40%.

Other historical earthquakes in Kentucky include:

- **March 12, 1878**: A shock was reported at Columbus, Kentucky. A section of the bluff along the Mississippi River caved in rated as intensity V on the Modified Mercalli Scale.
- **October 26, 1915**, an earthquake at Mayfield was reported to have shaken pictures from walls and rated as intensity V on the Modified Mercalli Scale.
- **December 7, 1915**: A sharp earthquake with an epicenter near the mouth of the Ohio River occurred. Buildings were strongly shaken, windows and dishes rattled, and loose objects were shaken in western Kentucky and adjoining regions (intensity V-VI). The total felt area covered 60,000 square miles.
- **December 18, 1916**: Hickman experienced a strong shock. Reports indicated bricks were shaken from chimneys at Hickman and New Madrid, Missouri (intensity VI-VII).
- **March 2, 1924**: An earthquake near the point of the December 1915 event occurred. No damage was reported and the felt area was much less, about 15,000 square miles.
- **September 2, 1925**: A broad area of Kentucky, Illinois, Indiana, and Tennessee, estimated at about 75,000 square miles, was affected by an earthquake. It was apparently centered near Henderson, where some landslides were noted. At Louisville, about 100 miles distant, a chimney fell and a house reportedly sank.
- **July 27, 1980**: in Sharpsburg KY, M5.2, MMI VII, Louisville VI. An earthquake measuring 5.2 on the Richter scale occurred near Sharpsburg in Bath County and caused an estimated $3 million in damage; 269 homes and 37 businesses in nearby Maysville were damaged.
- **April 18, 2008**: M5.4, in Louisville II-V. See map below.



Source: http://pasadena.wr.usgs.gov/shake/ca/STORE/Xfnbk/ciim_display.html

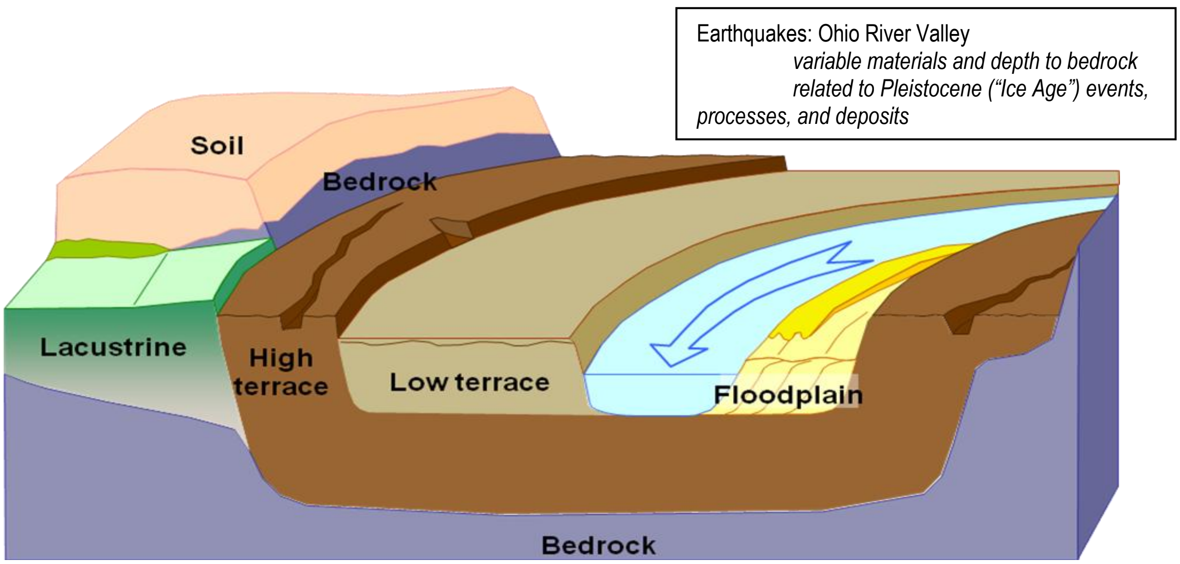
Louisville Metro Potential Earthquake Damage

Seismic events generate energy waves that attenuate as they move away from the epicenter of the event. The nature of the crustal rock of the Central U.S. results in a low degree of wave attenuation. Therefore, seismic shocks that occur in the central portion of the U.S. will affect a far greater area than similar events on the western coast.

The greatest hazard potential for earthquakes exists in highly populated areas, because these areas tend to have a greater number of tall buildings that are more vulnerable to seismic impact. Buildings and infrastructure (roads, bridges, etc.) built during the 1920s to 1960s are also generally more susceptible to seismic movement than newer construction.

Areas of softer soil and potential liquefaction generally result in increased vulnerability to the impacts of an earthquake. In Louisville Metro, old portions of the city and heavy industry are located on the alluvial deposits adjacent to the Ohio River. New portions of the city, including malls and the surrounding suburbs are constructed on the clay materials derived from limestone bedrock (ULY CIR 2004).

Jefferson County Geology: Earthquake issues



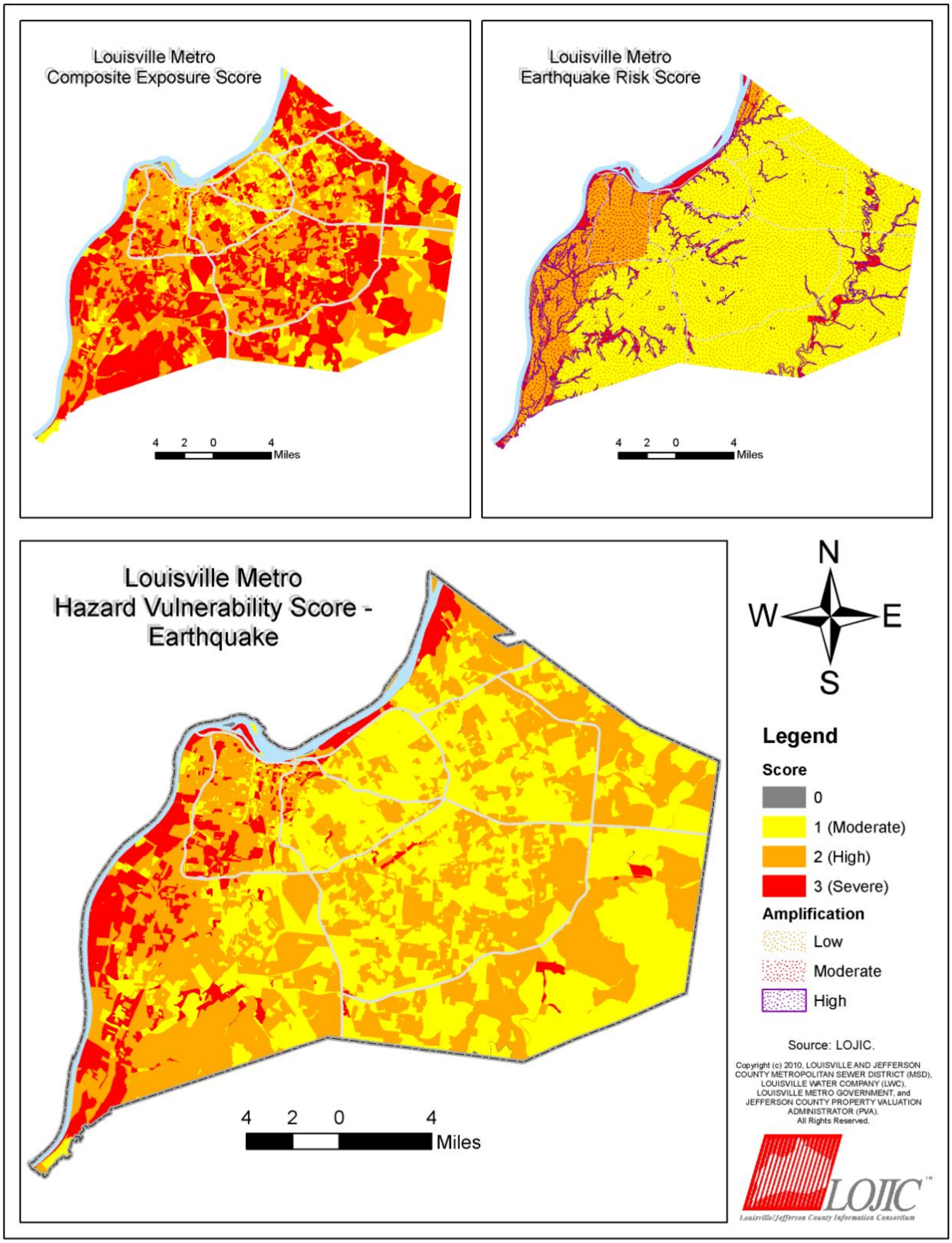
By W. Andrews, KGS

3.5.1.1 Assessing Vulnerability Overview: Earthquake

Earthquake Vulnerability Score = Exposure Score X Risk Score

Assessing vulnerability by census block was determined through creating the Earthquake Risk Score using the Area Affected Rank. The Area Affected Rank for Earthquake was calculated using new preliminary KGS soil data for Louisville Metro.

Recently KGS has developed enhanced preliminary Amplification soil data which can be used to display soil types more vulnerable to an Earthquake occurrence. The Area Affected Rank was determined using the Amplification soil data provided by KGS as the Hazard Boundary and then calculating the percent of the census block affected by the Amplification areas. The percentage of area affected by the Amplification areas was then calculated and ranked 0 to 3 (0 = No data, 1 = Moderate, 2 = High, and 3 = Severe). The Earthquake Vulnerability Score was calculated for each census block by multiplying the census block's Exposure Score by its Earthquake Risk Score.


Louisville Metro
Composite Exposure Score
4 2 0 4
Miles
Louisville Metro
Earthquake Risk Score
4 2 0 4
Miles
Louisville Metro
Hazard Vulnerability Score -
Earthquake
4 2 0 4
Miles
N
W
E
S
Legend
Score
0
1 (Moderate)
2 (High)
3 (Severe)
Amplification
Low
Moderate
High
Source: LOJIC.
Copyright (c) 2010, LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT (MSD), LOUISVILLE WATER COMPANY (LWC), LOUISVILLE METRO GOVERNMENT, and JEFFERSON COUNTY PROPERTY VALUATION ADMINISTRATOR (PVA). All Rights Reserved.
LOJIC
Louisville/Jefferson County Information Consortium

3.5.1.2 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: Earthquake

In order to determine structures that are vulnerable and estimated to be damaged during an earthquake the Project Staff used an enhanced HAZUS MH-MR4 run. GIS Staff was able to incorporate new soil data into HAZUS and complete a level 2 analysis for earthquake.

The HAZUS earthquake scenario used was a “Probabilistic 500 Year Earthquake". The HAZUS results show the following estimates:

- About 3,382 buildings will be at least moderately damaged. This is over 1.00% of the total number of buildings in the region.
- Structural loss estimate is $212,530,000.
- An estimated 40 buildings will be damaged beyond repair.

For a detailed description of this process, see Appendix 3.2 HAZUS Level 2 Earthquake Analysis.

3.6 Extreme Heat

Description: Temperatures that hover 10 degrees or more above the average high temperature for the region and last for several weeks are defined as extreme heat.

In the disastrous heat wave of 1980, more than 1,250 people died in the U.S. In addition the heat wave of 1995 more than 700 deaths in the Chicago area were attributed to heat. During the last two weeks of July 1999, the Midwest experienced a lengthy series of days with temperatures in excess of 90F. Before it was over, some 232 deaths were attributed to the heat in the 9-state Midwest region.

Our bodies dissipate heat by varying the rate and depth of blood circulation, by losing water through the skin and sweat glands, and as a last resort, by panting, when blood is heated above 98.6°F. Sweating cools the body through evaporation. However, high relative humidity retards evaporation, robbing the body of its ability to cool itself.

In the U.S.

Heat is the number one weather-related killer in the U.S. The NWS statistical data shows that heat causes more fatalities per year than floods, lightning, tornadoes, and hurricanes combined.

Based on the 10-year average from 2000 to 2009, excessive heat claims an average of 162 lives a year. By contrast, hurricanes killed 117; floods 65; tornadoes, 62; and lightning, 48.

NOAA's Watch, Warning, and Advisory Products for Extreme Heat

Each NWS Weather Forecast Office can issue the following heat-related products as conditions warrant:

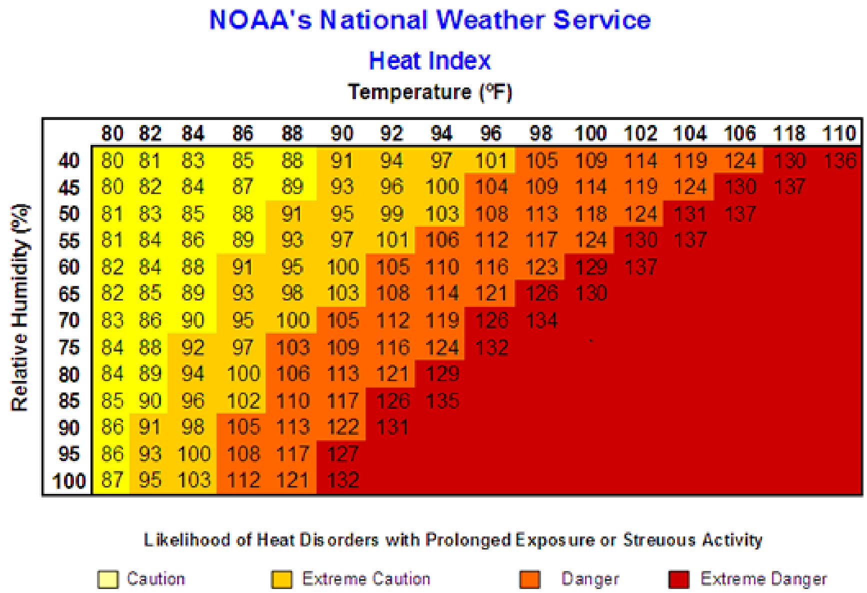
Excessive Heat Outlook: are issued when the potential exists for an excessive heat event in the next 3-7 days. An Outlook provides information to those who need considerable lead time to prepare for the event, such as public utilities, emergency management, and public health officials.

Excessive Heat Watch: is issued when conditions are favorable for an excessive heat event in the next 12 to 48 hours. A Watch is used when the risk of a heat wave has increased, but its occurrence and timing is still uncertain. A Watch provides enough lead time so those who need to prepare can do so, such as cities that have excessive heat event mitigation plans.

Excessive Heat Warning/Advisory is issued when an excessive heat event is expected in the next 36 hours. These products are issued when an excessive heat event is occurring, is imminent, or has a very high probability of occurring. The warning is used for conditions posing a threat to life or property. An advisory is for less serious conditions that cause significant discomfort or inconvenience and, if caution is not taken, could lead to a threat to life and/or property.

As an example, if the air temperature is 96°F (top of the table) and the relative humidity is 65% (left of the table), the heat index--how hot it feels--is 121°F. The NWS will initiate alert procedures when the Heat Index is expected to exceed 105°- 110°F (depending on local climate) for at least 2 consecutive days.

Important**:** Since heat index values were devised for shady, light wind conditions, exposure to full sunshine can increase heat index values by up to 15°F.



	80	82	84	86	88	90	92	94	96	98	100	102	104	106	118	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	126	130					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Source: http://www.weather.gov/om/heat/images/heat_index.png

Heat Index

The Heat Index Chart shown above indicates that temperatures exceeding 105°F may cause increasingly severe heat disorders with continued exposure and/or physical activity. Heat disorders generally have to do with a reduction or collapse of the body's ability to shed heat by circulatory changes and sweating or a chemical (salt) imbalance caused by too much sweating. When the body heats too quickly to cool itself safely, or when you lose much fluid or salt through dehydration or sweating, your body temperature rises and heat-related illness may develop.

Heat disorders share one common feature: the individual has been in the heat too long is exercised too much for his or her age and physical condition. Studies indicate that, other things being equal, the severity of heat disorders tend to increase with age. Conditions that cause heat cramps in a 17-year-old may result in heat exhaustion in someone 40, and heat stroke in a person over 60. Sunburn, with its ultraviolet radiation burns, can significantly retard the skin's ability to shed excess heat.

Heat Disorder Symptoms

- *Sunburn*: Redness and pain. In severe cases swelling of skin, blisters, fever, headaches. First Aid: Ointments for mild cases if blisters appear and do not break. If breaking occurs, apply dry sterile dressing. Serious, extensive cases should be seen by physician.
- *Heat Cramps*: Painful spasms usually in the muscles of legs and abdomen. Heavy sweating. First Aid: Firm pressure on cramping muscles or gentle massage to relieve spasm. Give sips of water. If nausea occurs, discontinue water.
- *Heat Exhaustion*: Heavy sweating, weakness, skin cold, pale and clammy. Pulse thready. Normal temperature possible. Fainting and vomiting. First Aid: Get victim out

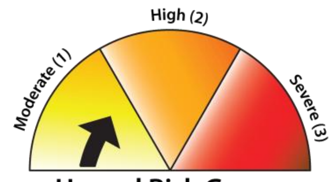
of sun. Once inside, the person should lay down and loosen clothing. Apply cool, wet cloths. Fan or move victim to air conditioned room. Offer sips of water. If nausea occurs, discontinue water. If vomiting continues, seek immediate medical attention.

- *Heat Stroke* (or sunstroke): High body temperature (106° F or higher). Hot dry skin. Rapid and strong pulse. Possible unconsciousness. First Aid: heat stroke is a severe medical emergency. Summon emergency medical assistance or get the victim to a hospital immediately. Delay can be fatal.

3.6.1 Extreme Heat Profile

SUMMARY OF EXTREME HEAT RISK FACTORS

Period of occurrence:	Summer
Number of Events to-date 1983-2010:	11
Probability of event(s):	0.41
Warning time:	Several days of high temperatures hovering over 90 degrees.
Potential Impact(s):	Public health and safety, especially the elderly. Heavy use of water and electrical facilities due to air conditioners, fans, etc…
Past Damages	$9,027



Background: Temperatures that hover 10 degrees or more above the average high temperature for the region are defined by NOAA as extreme heat. A temperature of 90°F is significant in that it ranks at the "caution" level of the NOAA's Apparent Temperature chart even if humidity is not a factor.

Kentucky Historical Impact

The 1952 heat wave lacked the intensity of other heat waves but it did have duration. According to the Kentucky Division of Forestry, numerous acres burned in 1952 due to the lack of precipitation. In Louisville alone, there was not a single day below the average temperature.

1990 and 1991 saw consecutive heat waves in which 1991 caused a statewide drought. 1991 is the third warmest year on record and also contained the third warmest summer as well as the second warmest spring.

The average temperature for August in Kentucky is around 77 degrees, give or take a few points per location. In 2007, the average was 85 degrees. During 2007, there were 67 days of temperatures over 90 degrees and 5 reaching over 100 degrees recorded. A federal disaster designation by the U.S. Department of Agriculture was declared allowing farmers in the state's $4 billion-a-year industry to seek emergency assistance, including low-interest loans to help pay for essential farm and living expenses.

History of Extreme Heat in Louisville Metro

Research has shown there is limited Louisville Metro data for tracking the damages, injuries, or deaths for extreme heat. Death certificates kept by the Jefferson County Health Department show six deaths due to extreme heat occurred during 1999 - 2002. These deaths occurred as following: four in 1999, 1 in 2000, and 1 in 2002.

Other Extreme Events include:

- **July 1999.** During the last two weeks of July 1999, the Midwest experienced a lengthy series of days with temperatures higher than 90 degrees F. While only a relatively small number of maximum temperature records were set, the combination of high heat, record dew points, strong solar inputs, and weak winds led to a dangerous situation for people. Before it was over, some 232 deaths were attributed to the heat in the 9-state area served by the MRCC; there were additional health, infrastructure, and economic impacts that were quite significant.

  The major loss of life was in large cities where the urban heat island amplified temperatures by 3 to 5 degrees or more. The majority of those who died were elderly persons, living alone in the inner city regions, and either were without air conditioning or without the funds to pay for continuous operation of their air conditioning units. Most of the people who died on the 29th and 30th lived in large cities with an old infrastructure of non-air-conditioned brick buildings.
- **August 2007.** Nearly 30 temperature records were set in central Kentucky in August 2007, including 105 degrees at Louisville on the 16th which tied the all-time record for the month. Louisville set a new record for consecutive 90 degree days (22). August 2007 became the hottest month ever recorded at Louisville and Bowling Green, and the 3rd hottest on record at Lexington.
- **Summer 2010** (June-July-August). The hottest on record for Louisville. This is true with respect to both AVERAGE temperature and MINIMUM daily temperature. The summer was the 2nd warmest on record with MAXIMUM daily temperature (1952 had higher maximum temps).

The table on the next page shows the NWS' overview of Louisville's average, maximum, and minimum temperatures from 1850 - 2010.

		Louisville			
Highest	Average	Average	Temperature	degrees F	
Days:	1-Jun	-	31-Aug		
Length	of	period:	92	days	
Years:	1850-2010				

Rank	Value	Ending			
1	82.3	8/31/2010			
2	80.9	8/31/1936			
3	80.0	8/31/2007			
4	79.6	8/31/1901,	8/31/1881,	8/31/1991	
7	79.5	8/31/1952,	8/31/1934		
9	79.1	8/31/1921			
10	79.0	8/31/2008,	8/31/1995,	8/31/1913	
13	78.9	8/31/1874			
14	78.8	8/31/1914,	8/31/1954,	8/31/1959	
17	78.7	8/31/1983,	8/31/1900,	8/31/1988	
20	78.6	8/31/1980			

		Louisville			
Highest	Average	Maximum	Temperature	degrees F	
Days:	1-Jun	-	8/31/2010		
Length	of	period:	1-Apr	days	
Years:	1850-2010				

Rank	Value	Ending			
1	91.9	8/31/1952			
2	91.6	8/31/2010			
3	91.3	8/31/1936			
4	90.8	8/31/1954			
5	90.7	8/31/1953			
6	90.3	8/31/2007			
7	90.2	8/31/1988			
8	90.1	8/31/1959			
9	89.9	8/31/1991,	8/31/1901		
11	89.7	8/31/1881			
12	89.5	8/31/1983			
13	89.3	8/31/1913			
14	89.1	8/31/1894			
15	88.9	8/31/1914			
16	88.8	8/31/1887,	8/31/1980,	8/31/2008	
19	88.7	8/31/1948,	8/31/1934		

		Louisville			
Highest	Average	Minimum	Temperature	degrees F	
Days:	1-Jun	-	31-Aug		
Length	of	period:	92	days	
Years:	1850-2010				

Rank	Value	Ending			
1	73.0	8/31/2010			
2	70.5	8/31/1936			
3	70.2	8/31/1934			
4	70.0	8/31/1874			
5	69.8	8/31/1921,	8/31/1995		
7	69.6	8/31/2007			
8	69.5	8/31/1881			
9	69.4	8/31/1901			
10	69.3	8/31/2008,	8/31/1944,	8/31/1943	
13	69.2	8/31/1991			
14	68.8	8/31/1900,	8/31/2006		
16	68.7	8/31/1914,	8/31/1913,	8/31/1876,	8/31/1878
20	68.6	8/31/1898			

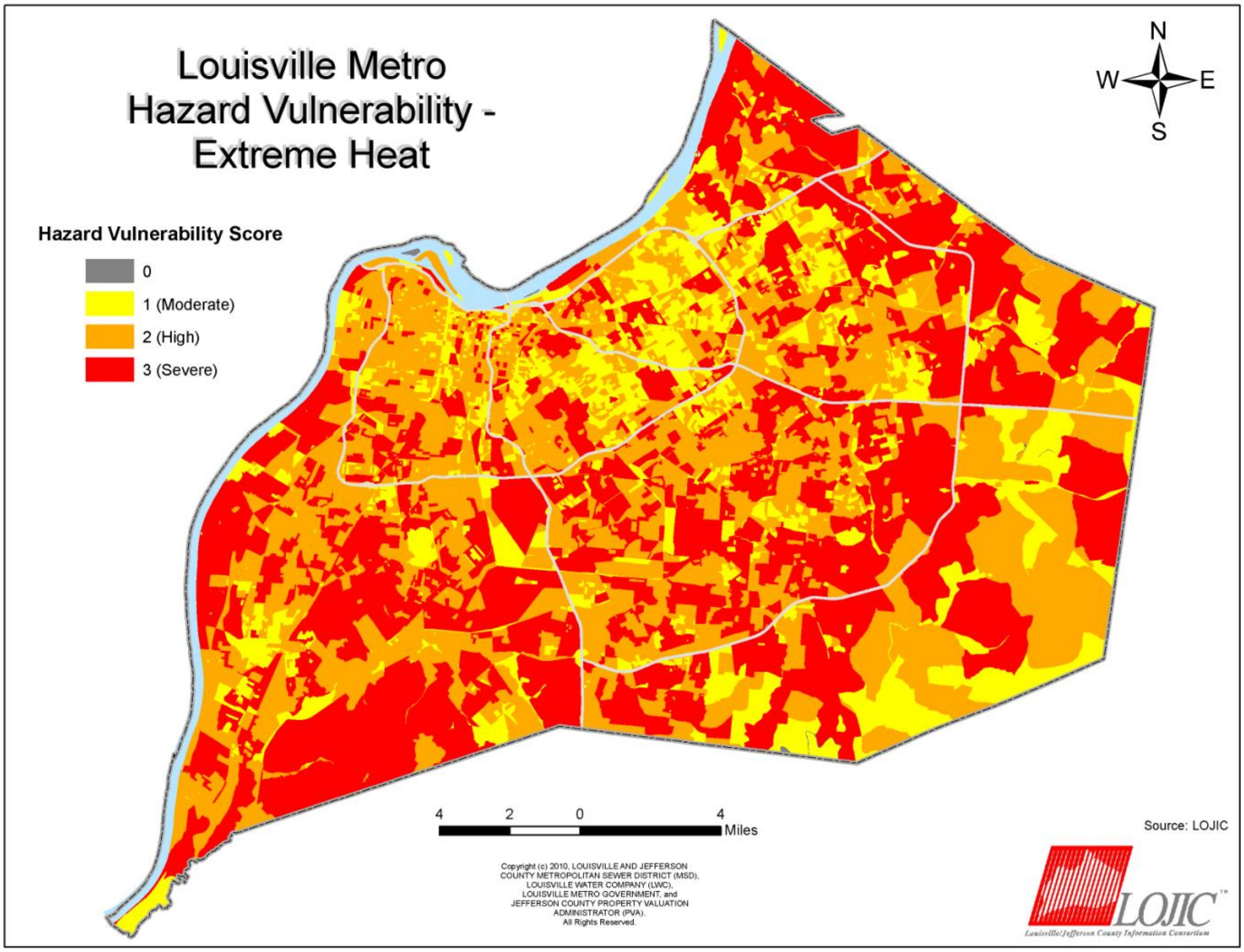
Extreme Heat Impacts: Main impacts are to public health and safety, especially the elderly. Additionally, heavy use of utilities (electric and water) cause a strain on the system due to air conditioners, fans, and water usage, etc…

3.6.1.1 Assessing Vulnerability Overview: Extreme Heat

Extreme Heat Vulnerability Score = Exposure Score X Risk Score

The Extreme Heat Vulnerability Score was difficult to calculate. Currently Louisville Metro has no real spatial data that can be calculated to determine vulnerable areas to Extreme Heat.

Extreme Heat is the type of hazard that typically affects a county the size of Louisville Metro equally. With that being said it was determined to use the Exposure Score map to display the Extreme Heat Vulnerability Score based on the assumption that the entire county is equally vulnerable to Extreme Heat. The Exposure Score does provide a visual display of areas that could be harder hit by Extreme Heat based on the assets that are within each census block.



3.6.1.2 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: Extreme Heat

Identifying structures and estimating potential losses for Extreme Heat is very difficult at this time. Without any current spatial data that truly identifies Extreme Heat hazard boundaries it is assumed that the entire county has equal vulnerability and the potential to be damaged from Extreme Heat.

The total number of structures in Louisville is 263,146 with a replacement value of $38,017,288,909.

3.7 Flood

Description: A flood is a natural event for rivers and streams and is caused in a variety of ways. Floods can be slow, or fast rising, but generally develop over a period of days. Winter or spring rains, coupled with melting snows, can fill river basins too quickly. Torrential rains from decaying hurricanes or other tropical systems can also produce flooding. The excess water from snowmelt, rainfall, or storm surge accumulates and overflows onto the banks and adjacent floodplains.

Floods are generally the result of excessive precipitation, and can be classified under two categories: *flash floods*, the product of heavy localized precipitation in a short time period over a given location; and *general floods*, caused by precipitation over a longer time period and over a given river basin.

In the U. S.

Flooding is the most frequent and costly natural hazard in the U S. Property damage from flooding now totals over $1 billion each year in the U.S. More than $4 billion is spent on flood damage in the U.S. each year.

During the 20th century, floods were the number one natural disaster in the U.S. in terms of number of lives lost and property damage.

In Kentucky, the severity of a flooding event is determined by a combination of stream and river basin topography and physiography, precipitation and weather patterns, recent soil moisture conditions and the degree of vegetative clearing. Flood currents also possess tremendous destructive power as lateral forces can demolish buildings and erosion can undermine bridge foundations and footings, leading to the collapse of structures.

Flash flooding events usually occur within minutes or hours of heavy amounts of rainfall, from a dam or levee failure, or from a sudden release of water held.

General floods are usually longer-term events and may last for several days. The primary types of general flooding include riverine flooding and urban flooding.

What is a Flood?

A flood, as defined by the National Flood Insurance Program (NFIP) is a general and temporary condition of partial or complete inundation of two or more acres of normally dry land area, or of two or more properties from:

- Overflow of inland or tidal waters;
- Unusual and rapid accumulation of runoff of surface waters from any source;
- A mudflow; or,
- A collapse or subsidence of land along the shore of a lake or similar body of water as a result of erosion or undermining caused by waves or currents of water exceeding anticipated cyclical levels that result in a flood.

Periodic flooding of lands adjacent to rivers, and streams is a natural and inevitable occurrence that can be expected to take place based upon established recurrence intervals. The recurrence interval of a flood is defined as the average time interval, in years, expected between a flood event of a particular magnitude and an equal or larger flood. Flood magnitude increases with increasing recurrence interval. A "floodplain" is the lowland area adjacent to a river, lake, or ocean.

Floodplains are designated by the frequency of the flood that is large enough to cover them. One way of expressing the flood frequency is the chance of occurrence in a given year, which is the percentage of the probability of flooding each year. For example, the 100-year flood has a 1% chance of occurring in any given year.

Types

Floods are the result of a multitude of naturally occurring and human-induced factors, but they all can be defined as the accumulation of too much water in too little time in a specific area. Types of floods include regional floods, river or riverine floods, flash floods, urban floods, ice-jam floods, storm-surge floods, and debris, landslide, and mudflow floods. For information on dam- and levee-failure floods, see Dam Failure in this section of the Plan. For information on landslides, see Landslide in this section of the Plan.

- *Regional Flooding* can occur seasonally when winter or spring rains coupled with melting snow fill river basins with too much water too quickly. The ground may be frozen, reducing infiltration into the soil and thereby increasing runoff. Extended wet periods during any part of the year can create saturated soil conditions, after which any additional rain runs off into streams and rivers, until river capacities are exceeded. Regional floods are many times associated with slow-moving, low-pressure or frontal storm systems including decaying hurricanes or tropical storms.
- *River or Riverine Flooding* is a high flow or overflow of water from a river or similar body of water, occurring over a period of time too long to be considered a flash flood. Riverine flooding is a function of excessive precipitation levels and water runoff volumes within the watershed of a stream or river.

Common Flood-Related Terms

100-Year Flood Plain. The area that has a 1% chance, on average, of flooding in any given year. (Also known as the Base Flood.)

500-Year Flood Plain. The area that has a 0.2% chance, on average, of flooding in any given year.

Base Flood. Represents a compromise between minor floods and the greatest flood likely to occur in a given area. The elevation of water surface resulting from a flood that has a 1% chance of occurring in any given year.

Floodplain. The land area adjacent to a river, stream, lake, estuary, or other water body that is subject to flooding. This area, if left undisturbed, acts to store excess floodwater. The floodplain is made up of two sections: the floodway and the flood fringe.

Floodway. The NFIP floodway definition is "the channel of a river or other watercourse and adjacent land areas that must be reserved, in order to discharge the base flood without cumulatively increasing the water surface elevation more than one foot." The floodway carries the bulk of the floodwater downstream and is usually the area where water velocities and forces are the greatest. NFIP regulations require that the floodway be kept open and free from development or other structures that would obstruct or divert flood flows onto other properties.

Flood Fringe. The flood fringe refers to the outer portions of the floodplain, beginning at the edge of the floodway and continuing outward.

Riparian. Located on the banks of a stream.

- *Flash Floods* are quick-rising floods that usually occur as the result of heavy rains over a short period of time, often only several hours or even less. Several factors can contribute to flash flooding. Among these are rainfall intensity, rainfall duration, surface conditions, and topography and slope of the receiving basin. Flash floods can occur within several minutes to several hours and with little warning. They can be deadly because they produce rapid rises in water levels and have devastating flow velocities. Most flash flooding is caused by slow-moving thunderstorms in a local area or by heavy rains associated with hurricanes and tropical storms. Although flash flooding occurs often along mountain streams, it is also common in urbanized areas where much of the ground is covered by impervious surfaces.
- *Urban Flooding* is possible when land is converted from fields or woodlands to roads and parking lots; thus, losing its ability to absorb rainfall. Urbanization of a watershed changes the hydrologic systems of the basin. Heavy rainfall collects and flows faster on impervious concrete and asphalt surfaces. The water moves from the clouds, to the ground, and into streams at a much faster rate in urban areas. Adding these elements to the hydrological systems can result in floodwaters that rise very rapidly and peak with violent force. During periods of urban flooding, streets can become swift moving rivers and basements can fill with water. Storm drains often back up with vegetative debris causing additional, localized flooding.
- *Ice-Jam Flooding* occurs on rivers that are totally or partially frozen. A rise in stream stage will break up a totally frozen river and create ice flows that can pile up on channel obstructions such as shallow riffles, log jams, or bridge piers. The jammed ice creates a dam across the channel over which the water and ice mixture continues to flow, allowing for more jamming to occur. Backwater upstream from the ice dam can rise rapidly and overflow the channel banks. Flooding moves downstream when the ice dam fails, and the water stored behind the dam is released. At this time the flood takes on the characteristics of a flash flood, with the added danger of ice flows that, when driven by the energy of the flood-wave, can inflict serious damage on structures. An added danger of being caught in an ice-jam flood is hypothermia, which can quickly kill.
- *Debris, Landslide, and Mudflow Flooding* is created by the accumulation of debris, mud, rocks, and/or logs in a channel, forming a temporary dam. Flooding occurs upstream as water becomes stored behind the temporary dam and then becomes a flash flood when the dam is breached and rapidly washes away. Landslides can create large waves on lakes or embayments and can be deadly.

Urban areas are susceptible to flash floods because a high percentage of the surface area is composed of impervious streets, roofs, and parking lots where runoff occurs very rapidly. Floodwaters accelerated by steep stream slopes can cause the flood-wave to move downstream too fast to allow escape, resulting in many deaths.

Factors determining the severity of floods include:

- Rainfall intensity and duration
    - A large amount of rain over a short time can result in flash flooding
    - Small amounts may cause flooding where the soil is saturated

  - Small amounts may cause flooding if concentrated in an area of impermeable surfaces
- Topography and ground cover
- Water runoff is greater in areas with steep slopes and little vegetation

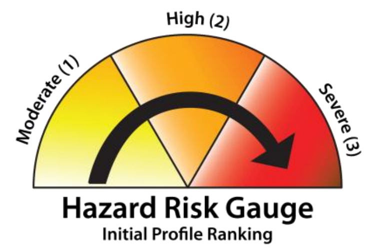
Flood Facts for the U. S.

- On average, there are about 145 deaths each year due to flooding. 80% of flood deaths occur in vehicles, and most happen when drivers try to navigate through floodwaters.
- Only six inches of rapidly moving floodwater can knock a person down and a mere two feet of water can float a vehicle.
- One-third of flooded roads and bridges are so damaged by water that any vehicle trying to cross stands only a 50% chance of making it to the other side.
- About one-third of insurance claims for flood damages are for properties located outside identified flood hazard areas.

3.7.1 Flood Profile

SUMMARY OF FLOOD RISK FACTORS

Period of occurrence:	Ohio River: December through May Flash Floods: anytime, but primarily during Summer rains
Number of Events to-date: 1964-2010	41
Probability of event(s):	0.89
Warning time:	River flooding – 3 –5 days Flash flooding – minutes to hours Out-of-bank flooding – several hours/days
Potential Impact(s):	Impacts human life, health, and public safety. Utility damage and outages, infrastructure damage (transportation and communication systems), structural damage, fire, damaged or destroyed critical facilities, and hazardous material releases. Can lead to economic losses such as unemployment, decreased land values, and Agro-business losses. Floodwaters are a public safety issue due to contaminants and pollutants.
Past Damages:	$208,298,243



Background: Flooding is the most significant natural hazard in Kentucky. Major flooding occurs within the state almost every year and it is not unusual for several floods to occur in a single year. Flooding is Kentucky's most costly natural disaster. The economic, social, and physical damage resulting from floods can be severe.

Because Flood is the most severe hazard in Louisivlle Metro, the following risk assessment is divided into 11 watershed assessments. The the Community Rating System (CRS) criterion. Similar to the other sections, a general countywide overview of the hazard provides a general overview. A detailed watershed breakdown follows describing each watershed's risk assessment.

National Flood Insurance Program

Louisville Metro became an NFIP community in 1978. The Flood Insurance Rate Maps (FIRM), updated in 2006, is used to enforce floodplain regulations and the local floodplain ordinance.

CRS Program

Beginning in 1990, Louisville volunteered to join the CRS (Community Rating System) Program. The Louisville/Jefferson County Metropolitan Sewer District (MSD) is the CRS Program Coordinator and is responsible for completion of all CRS activities. Since 2008, Louisville Metro ranks as a Class 5 Rating due to strong stormwater, floodplain, mapping, and emergency service programs. As a result, Louisville metro residents receive a 25% discount on flood insurance premiums. A Class 5 Rating is the highest-class rating in Kentucky.

History of Flooding in Louisville Metro

The following table shows the flood-related Presidentially Declared Disasters for Louisville Metro.

Disaster Number	Declaration Date	Disaster Type
568	12/12/1978	Severe Storms, Flooding
821	2/24/1989	Severe Storms, Flooding
1163	3/4/1997	Flooding
1471	6/3/2003	Flooding, Landslide, Severe Storm, & Tornado
1855	8/14/2009	Severe Storms, Straight-line Winds, and Flooding

In general, the two most common types of flooding that occur in Louisville Metro area are flash floods and Ohio River flooding.

Newspaper accounts and historical records show that during the 19th century large Ohio River floods occurred in 1832, 1847, 1859, 1867, 1883, and 1884. Major floods in the 20th century have occurred in 1907, 1913, 1933, 1937, 1945, 1948, 1964, and 1997. Thus, it can be seen that serious flooding has occurred in the Louisville area on the average of about once every 10 years.

Ten Greatest Recorded Flood Events of the Ohio River

Month	Year	NGVD Elevation Upper Gauge
February	1883	447.5
February	1884	449.7
January	1907	444.4
January	1913	442.5
April	1913	447.4
January	1937	460.2
March	1945	450.1
April	1948	444.0
March	1964	449.2
March	1997	445.1

The normal elevation of the upper pool of the Ohio River is approximately 420' above mean sea level (NGVD). Overbank flooding occurs at approximate elevation 430.5', and the base flood elevation (BFE) varies between 443' and 455'.

The major flash flooding problem in Louisville/Jefferson County is related to out-of-bank flash flooding. Out-of-bank flooding is defined as flooding that occurs when the natural embankments of a watercourse are breached. Additionally, ponding also may result in certain areas, at their lowest elevations. The community is also vulnerable to other flooding situations due to street runoff, erosion, and sewer and drainage problems.

The main flood season for the Ohio River is between the months of January and May. All of the highest floods on record have resulted from general heavy rains throughout the Ohio River Basin. In both summer and fall, intense local thunderstorms also can contribute significantly to local flash flooding and interior drainage problems.

Duration of Floods

NWS Reports for Louisville

- **Since 1986** there have been 71 Flash Flood Warnings issued for Jefferson County
- **Most in one day:** 5 on March 1, 1997 and August 4, 2009
- Since 1871 there have been seven calendar days on which ***more than 5"*** of rain have fallen (at the official city observing site)
- **Heaviest 1-day rainfall:** 10.48" March 1, 1997 (Kentucky state record)

The average duration of Ohio River floods of record in Louisville Metro is about 12 days. However, the sustained flood duration in 1937 was 23 days, in 1945 it was 18 days, and in 1964 and 1997 it was 14 days. The rate of rise at levels above flood stage varies in relation to rainfall and runoff rates for specific storms. Typical rates of rise for the Ohio River, at levels above flood stage, range from 2.5 to 5 inches per hour with the record rate of rise being 4.7 feet in 12 hours and 8.4 feet in 24 hours in 1964.

Local flood data detail

Following are examples of the larger local flood events.

- **January 1913:** The New Year in 1913 brought extensive rains to Kentucky and surrounding states causing every major river and stream in Kentucky to flood. Kentucky's total average rainfall for January was 11.41 inches, three times the normal amount. The U.S. Weather Bureau described the lowland areas of the state as being "vast inland seas". The Monthly Weather Review for January of that year collected details of the damage in dollar amounts. For the Louisville district, it reported property damages from the flood at $200,000, a very large sum for 1913. Total crop losses in the Louisville district totaled $50,000.
- **January 1937:** In January of 1937, rains began to fall throughout the Ohio River Valley; eventually triggering what is known today as the "Great Flood of 1937". Overall, total precipitation for January was four times its normal amount in the areas surrounding the river. In fact, there were only eight days in January when the Louisville station recorded no rain. These heavy rains, coupled with an already swollen river, caused a rapid rise in the river's level.

  The morning of January 24 the entire Ohio River was above flood stage. In Louisville, the river rose 6.3 feet from January 21-22. As a result, the river reached nearly 30 feet above flood stage. Louisville, where light and water services had failed, was the hardest hit city along the Ohio River. On January 27, the river reached its crest at 460 feet above sea level or 40 feet above its normal level, which is well over a 100-year event. Almost 70 percent of the city was under water, and 175,000 people were forced to leave their homes. The U.S. Weather Bureau reported that total flood damage for the entire state of Kentucky was $250 million, an incredible sum in 1937. The number of flood-related deaths rose to 190. The flood completely disrupted the life of Louisville, inundating 60% of the city and 65 square miles.

- **March 1945:** Although the Great Flood of 1937 gets most of the attention, and perhaps deservedly so, the flood that beset the Ohio River Valley eight years later was also extremely damaging. While 1937 is the flood of record at Louisville, 1945 is in second place (albeit a distant 2nd), with a peak stage at Louisville of 74.4 feet. This stage is about eleven feet below the 1937 stage, and ties with the stage set during the devastating 1884 flood.

Quincy Street looking West from Adams Street.

  As is almost always the case with massive Ohio River floods, snow melt had very little impact. The deepest snow cover at Louisville between New Year's Day and the flood was only 3 inches on the 29th of January, and that melted away in a few days. The bulk of the heavy rain that caused the flood fell during a three week period leading up to the flood. Rainfall during that time was over 500% of normal in southern Indiana, and around 400% of normal along the length of the Ohio River

  The rain came in four main waves, on February 20-21, February 25-26, March 1-2, and March 5-6. February 26 still stands as Louisville's 5th wettest February day on record (2.85"), and March 6 is the 10th wettest March day on record (2.66"). March 1945 is the 3rd wettest March on record, and February 1945 is actually only #19 on the list. However, instead of looking at calendar months, the period February 20 - March 8, 1945 is the second wettest such period on record at Louisville (1997 is #1).

- **March 1964**: In 1964, the community experienced its third greatest flood of the 20th century. This flood approximated the 100-year base flood. Most of the flood damage occurred in the southwest section of the county with about 1,200 homes being flooded. Property damage was estimated at $3,600,000.

- **December 1978:** A storm entered the southwest corner of Kentucky and moved northeast producing record-breaking rainfall totals for the entire area. On December 3, the Louisville Metro area received 2.77 inches of rain. Severe flooding occurred on the Licking, Kentucky, Salt, Green, and Ohio Rivers. Thirty-seven Kentucky counties received a federal disaster declaration due to five lives lost, and property damage at approximately $50 million. Flooding concentrated in Louisville and upstream with total damages of approximately $20 million.

> **Floodplain Administrator**
>
> Since January 1987, the Louisville Jefferson County MSD coordinates Louisville Metro's flood management efforts, with support from FEMA. MSD conducts ongoing flood hazard profiling and modeling, using a watershed-based approach.
>
> Additional information is available at the MSD website at: http://www.msdlouky.org/

- **February 1989:** Precipitation was above normal in Kentucky in the months of December 1988 and January 1989, following an extreme drought during the summer and fall of 1988. By the end of January 1989, minor flooding had occurred on most rivers and streams in Kentucky, setting the stage for major flooding in February 1989. Between February 12-16 rain totals were 8 to 12 inches for an area stretching from Paducah to Lexington. During February, the Louisville Metro area received 9.02 inches of rain, one of the highest totals on record. The President issued a disaster declaration for 67 counties in Kentucky.
- **May 26 1996:** Several roads across southern Jefferson County were closed due to high waters as 4 inches of rain fell between 11 pm EST May 25 and 11 am EST May 26. Area creeks were already backed up due to the near-flooded Ohio River. Fifty residents of a nursing home on Dixie Highway had to be relocated when a sump pump failure allowed the halls to be filled with water.
- **March 1997**: 01 Mar 1997 - 03 Mar 1997: Numerous strong thunderstorms along a stalled out warm front triggered a record 24-hour rainfall for Louisville Metro. On March 1, the Louisville Metro area received 7.22 inches of rain, the highest total on record for one-day. The combination of flooding and/or flash flooding from the record rainfall resulted in an estimated 50,000 homes affected by flooding. Many of these homes had basements entirely flooded with water into the main floor. The Ohio River crested on March 7 in Louisville at about nearly 15' feet above flood stage.

  Inland Ponding: The hardest hit areas were in the southwestern section of Louisville Metro along the Ohio River. Two other inland areas hit hard were in the Pond Creek watershed south of Louisville and along Floyds Fork in the east. More than 50,000 residences experienced some level of flooding. In addition, high water briefly closed Interstates 64 and 65, as well as scores of secondary roads. The flood pump station at the mouth of Pond Creek alone moved 2.6 billion gallons of water a day, draining the flood-ravaged neighborhoods of Okolona and Fairdale. During the first few days of the flood, MSD received more than 7,000 calls mostly about sewer backups and surface flooding. MSD estimated that as many as 25,000 customers may not have reported basement backups during the March 1997 flood.

  Ohio River Flood: As floodwaters began receding in southern Louisville Metro, the flood stage of the river became a threat. A week after the rains, the Ohio River crested in Louisville 15.8 feet above flood stage. Flooding along the Ohio River continued for two weeks throughout Kentucky. The President declared over 87 of the 120 counties in Kentucky federal disaster areas eligible for federal aid statewide.

  Damages: Damage was estimated at $65 million not including the river flooding on the Ohio River. The southwest floodwall closures passed their first test and protected many areas that flooded in 1964 and 1978. The Ford factory on Fern Valley Road had damage to up to 1,500 Explorers. 24-hour rainfall totals beginning around February 28 to March 1 ranged from around 6 inches along the Ohio River to 11.5 inches across the communities of Okolona and Fairdale in the southern part of the county. The previous record 24-hour total was 6.97 inches. An estimated 2,500 homes in numerous subdivisions in Okolona and Fairdale and across other parts of the county had to be evacuated with hundreds relocated in temporary shelters. Okolona and Fairdale lie in the Pond Creek floodplain, which was formerly swampland.

National Guard had to get many of these people out by boat or dump trucks. Thousands of cars were evacuated or stalled out due to the high waters. Numerous rescues were made with people trapped in cars and in houses. Bloated storm sewers popped off manhole covers that left cars quickly inundated in advancing high water. Several roads were closed around the Jefferson County Memorial Forest due to mudslides. A 16-year-old boy was killed near Jeffersontown as his van was swept off the road by the swollen Chenoweth Creek. Numerous roads including parts of Interstate 65 and 64 were closed through the morning of March 2. Because of all the damage, the County-Judge Executive declared the county a state of emergency.

In Kentucky, twenty-one people were killed and an estimated $250 to $500 million in damages where caused by the flooding. The damages incurred by the entire Ohio River flood exceeded $1 billion and over 67 deaths. Fortunately, floodwalls partially protected Louisville, preventing even more damage.

2005 – 2010 Flood Events

Following are summaries of NCDC flood events with property damage for 2005 - 2010. These events happened since the final plan adoption for the Louisville Metro Natural Hazards Mitigation Plan (May 2005).

2005- 2010 Flood Events

Location	Date	Time	Type	Mag	Death	Injuries	Property Damage
Countywide	05/19/2005	07:34 PM	Flash Flood	N/A	0	0	20K
Louisville	03/12/2006	10:00 AM	Flash Flood	N/A	0	0	0
Countywide	07/14/2006	07:20 PM	Flash Flood	N/A	0	0	0
Louisville	07/21/2006	05:20 PM	Flash Flood	N/A	0	0	0
Prospect	08/27/2006	08:25 PM	Flash Flood	N/A	0	0	0
Countywide	09/22/2006	10:56 PM	Flash Flood	N/A	0	0	500K
Countywide	09/23/2006	02:13 PM	Flash Flood	N/A	0	0	0
Highlands	12/15/2007	13:00 PM	Flood	N/A	0	0	30K
Highlands	02/06/2008	00:23 AM	Flash Flood	N/A	0	0	0
(Lou) Bowman Field Louisville	02/06/2008	00:41 AM	Flash Flood	N/A	0	0	0
Ballardsville	03/04/2008	14:53 PM	Flash Flood	N/A	0	0	0
Louisville	03/19/2008	05:49 AM	Flash Flood	N/A	0	0	0
Louisville	03/19/2008	12:44 PM	Flood	N/A	0	0	0
Audubon Park	03/19/2008	23:20 PM	Flood	N/A	0	0	0
Valley Station	03/20/2008	04:50 AM	Flood	N/A	0	0	0

Location	Date	Time	Type	Mag	Death	Injuries	Property Damage
Okolona	04/03/2008	23:10 PM	Flash Flood	N/A	0	0	50K
Shively	05/08/2009	15:50 PM	Flash Flood	N/A	0	0	0
Ballardsville	07/30/2009	17:52 PM	Flood	N/A	0	0	0
St Dennis	08/04/2009	07:00 AM	Flash Flood	N/A	0	0	45.0M
Highlands	08/04/2009	08:32 AM	Flash Flood	N/A	0	0	0
Worthington	08/10/2009	20:01 PM	Flash Flood	N/A	0	0	0
Highlands	09/20/2009	19:51 PM	Flash Flood	N/A	0	0	0
Valley Station	09/20/2009	21:23 PM	Flash Flood	N/A	0	0	0
Audubon Park	09/20/2009	22:04 PM	Flash Flood	N/A	0	0	0
				TOTALS	0	0	$45,600,000

- **September 22-23, 2006**: A slow-moving storm system brought torrential rains to the region on September 22 and 23, 2006, resulting in widespread flash flooding. Six people were killed in the Louisville NWS office's area of responsibility. It was the worst general flood since the March 1997 flood. It was the deadliest weather event in this area since seven people were killed in the flood of March 1-2, 1997, and the Super Outbreak of tornadoes on April 3, 1974 when 72 lives were lost.

  The Bent Creek Apartments in the Buechel area were flooded. More than 100 residents had to be evacuated to an area shelter. Interstate 64 between Cannons Lane and Interstate 71 was closed. Water covered many roads in the vicinity of Veteran's Hospital in Louisville. Three feet of water covered 29th Street. Two to three feet of water covered Brownsboro Road about half a mile east of the Mellwood Avenue intersection. Water rescues were conducted in the Lake Forest area and in Jeffersontown. Old Henry Road was flooded and impassable. Property Damage estimates was $500K. Thirty-two flood insurance claims were filed for this event with a total of approximately $1.7M for both structure and contents damages.

- **April 3, 2008**: A flood on the Ohio River covered local roads and caused damage to low-lying areas and structures. Several vehicles were submerged in the Louisville area, but no injuries or water rescues were reported. Numerous roads were closed due to flooding around the Louisville Metro area. Some of the closures included: a lane of Interstate 65 at the Woodbine exit, Third Street at Eastern Parkway, Breckinridge Lane at Six Mile Lane, Outer Loop at Preston Highway, and Outer Loop at New Cut Road. A frontal system and upper level low brought widespread heavy rains and flooding to central Kentucky. The event produced 40 flood insurance claims totaling $542,026 in structural and content damage.

In 2008, a flood on the Ohio River caused damage to low-lying areas along River Road.

- **August 4, 2009**: severe weather produced torrential rainfall in the Louisville Metro area with up to seven inches of rain falling in around two hours time. This created massive flash flooding issues across the northwest and central part of Louisville Metro and caused millions of dollars in damage in Louisville.

  A huge storm front moved south towards the Louisville downtown around 8 a.m. before heavy rain began falling. (By Matt Stone, *The Courier-Journal*) Aug. 4, 2009

  The heavy rain and thunderstorms also produced some hail and cloud to ground lightning that caused several fires, including one four-alarm apartment complex fire on the east side of Louisville. See the map for a 3-hour synopsis of the rainfall at the end of this section.

  Nearly 200 people were rescued by emergency workers from the tops of cars and houses. About 50 people were rescued by boat from a University of Louisville administrative office building. Two children were pulled from a swollen creek when neighbors saw them get swept away as they walked too close to the stream.

  Water was reported up to several feet deep in parts of Louisville. Most of the downtown Louisville area received flooding with many commercial buildings in the immediate downtown area having damage. Many roads in the downtown area had several feet of water covering them, with residential buildings taking on water in basements. Numerous homes on the west side of town were also damaged.

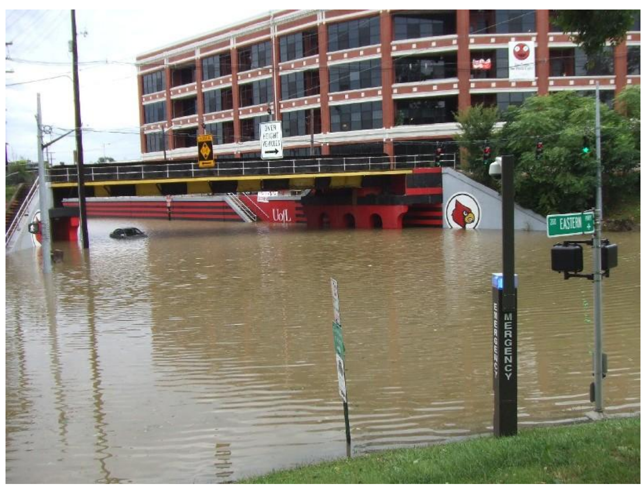
  

  Photo: Mike Howard, NWS

  Major flooding affected Churchill Downs and surrounding neighborhoods. Floodwaters poured into homes and engulfed Louisville's main public library downtown, several area hospitals, horse barns at Churchill Downs, and the University of Louisville campus. The entire basement of the Louisville Free Public Library was inundated with water causing damage to books, computers, vehicles, and other items. Thousands of books were destroyed at the Louisville downtown library, with a million dollars in damage.

The University of Louisville campus had several building damaged and flooded and water rescues had to be performed. Four of the U of L classroom buildings were closed for more than a month, resulting in a shuffling of numerous classroom locations.

Interstates 64, 65 and 264 were all closed for a period of time due to high water. Other water rescues were performed downtown as people became stranded in vehicles during rush hour traffic.

A Federal Disaster Declaration for Kentucky Severe Storms, Straight-line Winds, and Flooding was issued on August 14, 2009 (DR 1855). Louisville Metro citizens registered with FEMA for federal and Commonwealth disaster assistance following the August 4 severe weather and flooding. The registration period closed on October 13, 2009 with 12,288 registrations for Louisville Metro.

A summary of the Project Worksheets (PWs) submitted to KyEM for DR 1855 - Flooding is as following.

Total Eligible Applicants – 33: Total Projects (PWs) 252

Category A - $267,145.95 /PWs = 17

Category B - $925,187.42 /PWs = 38

Category C - $15,537.68 /PWs = 6

Category D - $0 /PWs = 0

Category E - $3,748,317.33 /PWs = 178

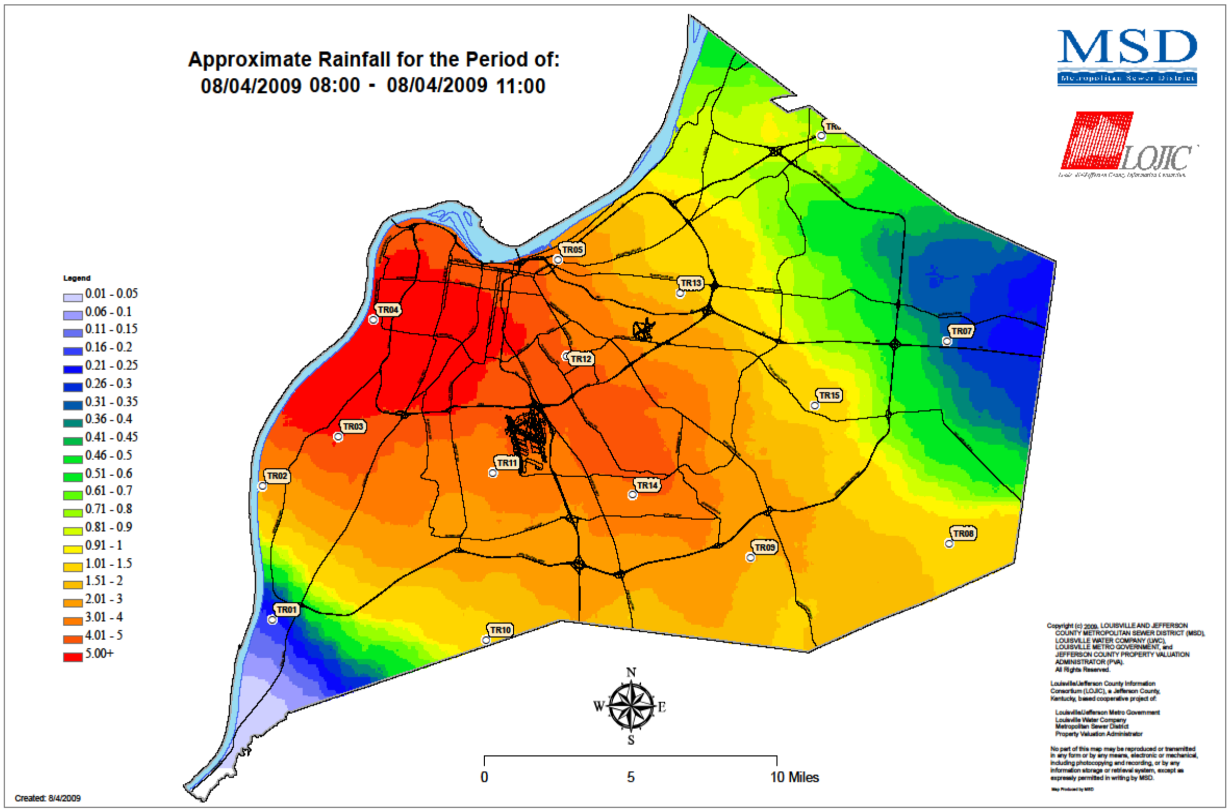
Category F - $1,000,350.85 /PWs = 9

Category G - $41,515.33 /PWs = 4

Total Project Amount - $599,805,456

August 4 2009 Flood Event, 3-Hour Map

* TR Symbols Shows Locations of Rain Gauges.



3.7.1.1 Repetitive Loss Areas

Louisville Metro has over 5,000 flood insurance policies and over 200 of these properties are Repetitive Loss Properties according to the 2009 NFIP insurance records and claims. Louisville Metro has the highest number of repetitive loss properties in Kentucky.

As the floodplain administrator, MSD utilizes the Louisville Metro's community's official repetitive loss list to determine repetitive loss areas. The official repetitive loss list is provided through FEMA according to flood insurance claims.

Repetitive Loss

§201.6(c)(2)(ii): The risk assessment in all plans approved after October 1, 2008 must also address NFIP insured structures that have been repetitively damaged by floods.

All Local Mitigation Plans approved by FEMA **must** address repetitive loss structures in the risk assessment by describing the types (residential, commercial, institutional, *etc.*) and estimate the numbers of *repetitive loss properties* located in identified flood hazard areas.

Louisville Metro recognizes repetitive loss properties as prime targets for mitigation projects. Following are definitions for the three categories of repetitive loss.

Repetitive loss structure locations are a trigger to the community that other adjacent properties may be at-risk, and can provide the community an opportunity to designate a repetitive loss area that reflects the vulnerability of a street or neighborhood.

Repetitive Loss Description

A property is considered repetitive loss when the structure has experienced more than one flood-related loss and received flood insurance for more than $1,000 in damages within a 10-year period.

Historical claims data also helps a community identify floodprone areas. The repetitive loss and historic claims areas were identified as part of the Flood Risk Score so that appropriate enforcement, mitigation, and emergency measures are taken. The following table depicts Louisville Metro's total number of Repetitive Loss and Historical Claims.

Severe repetitive loss property is defined as a residential property that is covered under an NFIP flood insurance policy and:

(a) That has at least four NFIP claim payments (including building and contents) over $5,000 each, and the cumulative amount of such claims payments exceeds $20,000; or
(b) For which at least two separate claims payments (building payments only) have been made with the cumulative amount of the building portion of such claims exceeding the market value of the building.

For both (a) and (b) above, at least two of the referenced claims must have occurred within any ten-year period, and must be greater than 10 days apart.

The table below summarizes the total number and claims of Repetitive Loss, Severe Repetitive Loss, and Historical Claims across Louisville Metro.

Variable	Totals	Losses
Repetitive Loss	171	$10,453,254
Severe Repetitive Loss	48	$8,812,064
Historical Claims	1,824	$4,002,099
TOTALS	**2,043**	**$23,267,417**

The following table summarizes Repetitive Loss and Severe Repetitive Loss Properties by Occupancy Type across Louisville Metro.

Variable	Single Family	Other Residential	Non-Residential	Assumed Condo	Other	Totals
Repetitive Loss	128	18	11	3	11	171
Severe Repetitive Loss	38	2	3	2	3	48
TOTALS	**166**	**20**	**14**	**5**	**14**	**219**

The table below displays the total number of Repetitive Loss Properties, Severe Repetitive Loss, and Historical Claims by the eleven watersheds. This data can be used to identify areas at risk located outside of the floodplain.

Total Number of Repetitive Loss Properties/Severe Repetitive Loss and Historical Claims by Watershed						
WATERSHEDS	Repetitive Loss (RL)	RL Losses	Historical Claims (HC)	HC Losses	Severe Rep Loss (SRL)	SRL Losses
Cedar Creek	0	$0.00	13	$16,283	1	$96,924
City/Ohio River	60	$3,895,813	175	$510,238	42	$7,403,632
Floyds Fork	7	$464,488	29	$3,649	0	0
Goose Creek	4	$519,720	35	$4,370	2	$388,885
Harrods Creek	0	$0.00	44	$10,834	1	$778,647
Middle Fork Beargrass Creek	8	$1,637,078	57	$540,803	0	0
Mill Creek	6	$30,511	156	$29,209	0	0
Muddy Fork Beargrass Creek	4	$141,039	21	$44,258	0	0
Pennsylvania Run	0	$0.00	5	$0.00	0	0
Pond Creek	53	$2,151,633	1,078	$1,966,268	1	$58,108
South Fork Beargrass Creek	29	$1,612,972	211	$876,187	1	$85,868
TOTALS	171	$10,453,254	1,824	$4,002,099	48	$8,812,064

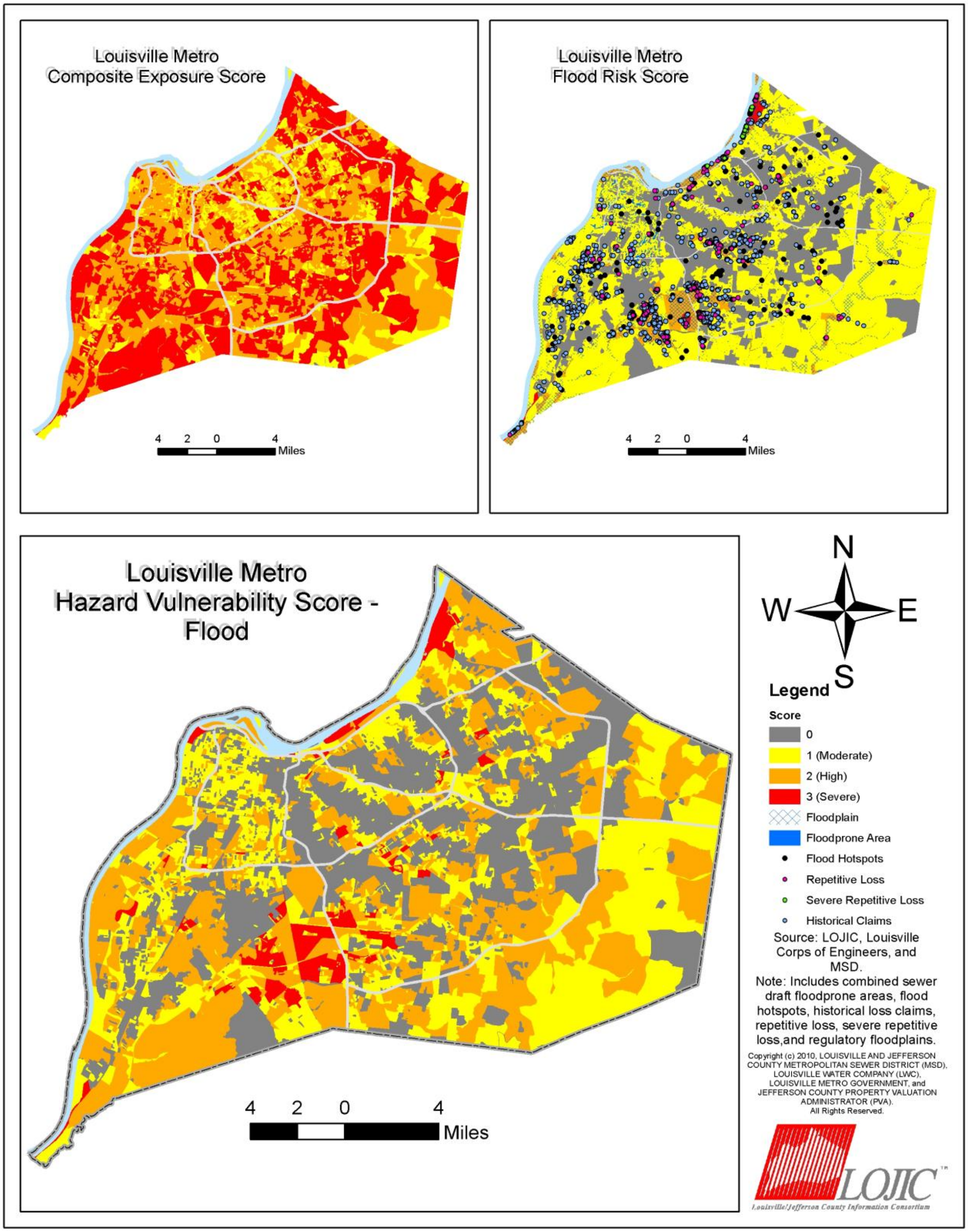
3.7.1.2 Assessing Vulnerability Overview: Flood

Flood Vulnerability Score = Exposure Score X Risk Score

Assessing vulnerability by census block was determined through creating the Flood Risk Score adding the Occurrence Rank and Area Affected Rank. The Occurrence Rank was determined by counting the four separate variables within each census block. Using data provided from KDOW and Louisville MSD the Project Staff identified Repetitive Loss Properties, Severe Repetitive Loss Properties, and Historical Claim Properties, along with flood hotspot data provided by NOAA. These three variables were identified and aggregated to individual census blocks. The Occurrence Rank provided an understanding of where high concentrations of flood events have occurred, thus producing areas of risk. Each variable was calculated individually and then added to together to build a composite Flood Occurrence Rank. Each rank followed these ranges 0 to 3 (0 = No data, 1 = Moderate, 2 = High, and 3 = Severe).

The Area Affected Rank was calculated by taking the percent of the census block affected by the Louisville MSD Regulatory Floodplain and the “Draft” Combined Sewer Floodprone Area study completed by the Louisville Corp of Engineers. The percentage of area affected by each of the mapped Flood potential area’s was then calculated and ranked 0 to 3 (0 = No data, 1 = Moderate, 2 = High, and 3 = Severe). Each Area Affected Rank was calculated separately and combined to build a composite Flood Area Affected Rank. Next, the Flood Occurrence Rank and Area Affected Rank scores were added together to produce the Flood Risk Score.

The Flood Vulnerability Score was calculated for each census block by multiplying the census block's Exposure Score by its Flood Risk Score. The flood vulnerability maps display each phase of the model in order (Exposure Score x Flood Risk Score) = Flood Hazard Vulnerability Score. This allows the reader to see all the pieces that created the Flood Hazard Vulnerability Score for each watershed.


Louisville Metro
Composite Exposure Score
4 2 0 4
Miles
Louisville Metro
Flood Risk Score
4 2 0 4
Miles
Louisville Metro
Hazard Vulnerability Score - Flood
4 2 0 4
Miles
N
W
E
S
Legend
Score
0
1 (Moderate)
2 (High)
3 (Severe)
Floodplain
Floodprone Area
Flood Hotspots
Repetitive Loss
Severe Repetitive Loss
Historical Claims
Source: LOJIC, Louisville Corps of Engineers, and MSD.
Note: Includes combined sewer draft floodprone areas, flood hotspots, historical loss claims, repetitive loss, severe repetitive loss,and regulatory floodplains.
Copyright (c) 2010, LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT (MSD), LOUISVILLE WATER COMPANY (LWC), LOUISVILLE METRO GOVERNMENT, and JEFFERSON COUNTY PROPERTY VALUATION ADMINISTRATOR (PVA). All Rights Reserved.
LOJIC
Louisville/Jefferson County Information Consortium

3.7.1.3 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: Flood

In order to determine structures that are vulnerable and estimated to be damaged during a Flood event the planning team used the Hazard Boundary Overlay methodology. The Hazard Boundaries used as the overlay were the Louisville MSD Regulatory Floodplain and the “Draft” Combined Sewer Floodprone Area study completed by the Louisville Corp of Engineers. These Flood potential maps display areas of mapped flood prone areas based on scientific studies, thus displaying areas where potential losses from Floods could occur.

The following table describes the total number of structures identified within the Louisville MSD Regulatory Floodplain and the replacement cost of those structures. This model estimates complete damage of each structure located within the Hazard Boundary.

FLOOD	STRUCTURES
COMMERCIAL	2,624
INDUSTRIAL	354
RESIDENTIAL	11,407
OTHER	622
TOTAL BUILDINGS	**15,007**
ESTIMATED LOSS	**$1,631,430,293**

References for Watershed Data

- **Water Quality in Jefferson County, Kentucky: A Watershed Synthesis Report, 2000-2007**

  Prepared by Department of Biology, University of Louisville and Louisville and Jefferson County MSD, December 2009

- **Stormwater Quality Management Plan** (SWQMP) Chapter 1.4

  Prepared by Louisville and Jefferson County (MSD), October 2008

  *Stormwater quality is addressed through the SWQMP

- **Louisville Metro Stormwater Management Master Plan (SMMP)**

  Prepared by Louisville and Jefferson County MSD, October 2010

  The primary objective for the SMMP is the promotion of stormwater drainage management practices in the context of a regional program.

3.7.2 Louisville Metro's Watersheds

In June 1997, MSD launched a watershed-based approach to managing its floodplain, wastewater, and stormwater programs. MSD's holistic overview of watershed management integrates service activities such as planning, enforcement, emergency management, best management practices, preservation, hydrology, hydraulics, and geography. The watershed approach also promotes a comprehensive effort to address multiple causes of water quality and habitat degradation in a watershed.

MSD recognizes that each watershed area presents its own set of challenges. The following is a map of the eleven natural watersheds.

A detailed Risk Assessment was performed for each watershed providing data for the following:

- Identifying Critical/Essential Facilities and Infrastructure located within the Regulatory Floodplain
- Assessing and quantifying natural and beneficial function areas
- Mapping known hazard areas (Regulatory Floodplain, Repetitive Loss Properties, Severe Repetitive Loss, Historic Claim Properties, Flood Hotspots, and the Draft Sewer Floodprone area zones (when appropriate)
- Assessing the impact flood will have on life, safety and health facilities and the effects on the communities economy through loss estimation
- Providing a description of known flood hazards, including source of water, depth of flooding, velocities, and identifying key warning time gauges.

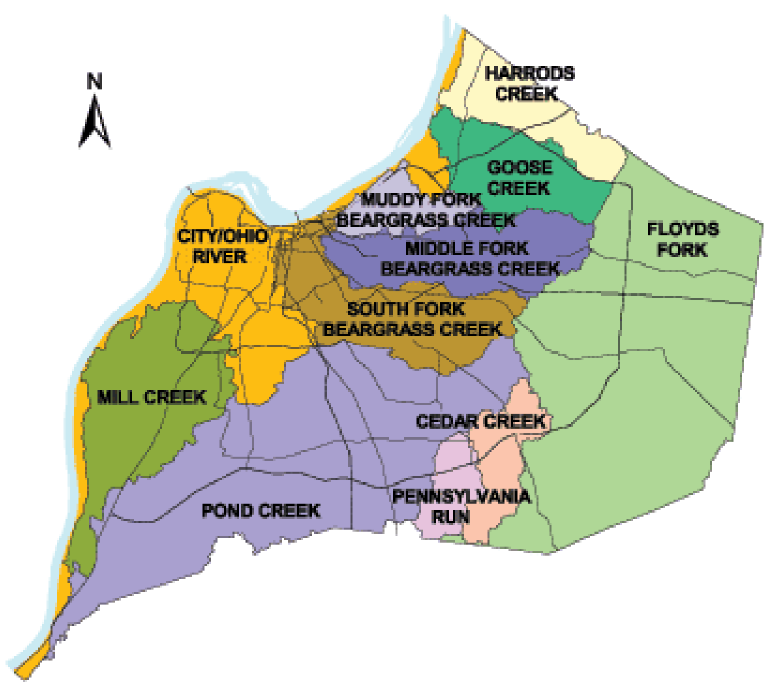
Watershed

Watershed. An area of land whose total surface drainage flows to a single outlet, such as a stream or creek.

In Jefferson County, all streams eventually drain into the Ohio River.

Watershed management. The analysis, protection, development, operation or maintenance of the land, vegetation, & water resources of a drainage basin for the conservation of all its resources for the benefit of its residents.

WATERSHEDS WITHIN JEFFERSON COUNTY



3.7.2.1 Watershed Characteristics

The following table displays important characteristics for each watershed. Included within the table are the following: drainage area, major stream networks that cause flooding, and the location of USGS stream gauges. The stream gauges provide data that can be useful during all phases of emergency/floodplain management. The gauges are useful in providing early warnings during an event, data for mapping, and water quality data.

WATERSHED CHARACTERISTICS			
11 Watersheds	Drainage Area (sq mi)	Major Stream Systems	USGS Stream Gauges
MIDDLE FORK BEARGRASS CREEK	25.1	Middle Fork Weicher Creek	Middle Fork @ Old Cannons Ln Middle Fork @ Lexington Rd
MUDDY FORK BEARGRASS CREEK	8.8	Muddy Fork	Muddy Fork @ Mockingbird Valley Rd
SOUTH FORK BEARGRASS CREEK	27.1	South Fork Buechel Branch	South Fork @ Trevilian Way South Fork @ River Rd
CEDAR CREEK	11.2	Cedar Creek	Cedar Creek @ Thixton Rd
FLOYDS FORK	103.9	Floyds Fork Chenoweth Run Pope Lick	Floyds Fork @ Old Taylorsville Rd Floyds Fork @ Bardstown Rd Chenoweth Run @ Ruckriegal Pkwy Chenoweth Run @ Gelhaus Ln
GOOSE CREEK	18.6	Goose Creek	Goose Creek @ Old Westport Rd Goose Creek @ US Hwy 42 Little Goose Creek @ US Hwy 42
HARRODS CREEK	15.3	Harrods Creek Wolf Pen Branch South Fork Harrods South Fork Hite	N/A
MILL CREEK[(4)]	34.2	Mill Creek Upper Mill Creek Big Run Cane Run Black Pond Creek	Mill Creek Cutoff @ Cane Run Rd Mill Creek @ Orell Rd
OHIO RIVER	39.8	Combined Sewer System	Ohio River @ 2nd Street Bridge Ohio River @ McAlpine Locks Ohio River @ Kosmosdale
PENNSYLVANIA RUN	6.9	Pennsylvania Run	Penn Run @ Mt Washington Rd
POND CREEK	89.3	Pond Creek Northern Ditch Southern Ditch Fern Creek	Pond Creek @ W Manslick Rd Pond Creek @ Pendleton Rd Northern Ditch @ Preston Hwy Fern Creek @ Old Bardstown Rd Brier Creek @ Pendleton Rd

3.7.2.2 Flood Hot Spots

After Storm Events. During wet weather events MSD Customer Specialists and maintenance crews inspect known trouble locations or “choke points” called Hot Spots to make sure they are not blocked and are flowing freely. This encompasses 25 miles of stream throughout the service area. This data was geo-coded and produced by Louisville’s Regional NOAA office.

3.7.2.3 Watershed Flood Risk

In order to understand the flood risk that is within each watershed Project Staff calculated several key requirements in the following tables. The table below displays existing buildings located in the regulatory floodplain by watershed. This data can be used to display economic issues based on the potential losses each watershed could observe based on the buildings identified within the floodplain and their corresponding replacement costs.

Existing Buildings Located in the Local Regulatory Floodplain by Watershed							
WATERSHEDS	# Bldg.	Bldg. Value	Residential Bldg	Commercial Bldg.	Industrial Bldg.	Other Bldg.	Basement Bldg.
CEDAR CREEK	24	$1,980,260.00	24	0	0	0	5
CITY/OHIO RIVER	548	$150,429,116.39	368	80	47	52	88
FLOYDS FORK	239	$33,568,762.08	168	12	6	53	106
GOOSE CREEK	210	$33,131,793.57	172	13	0	25	102
HARRODS CREEK	48	$13,930,701.81	31	5	0	12	27
MIDDLE FORK BEARGRASS CREEK	387	$142,528,230.07	234	130	4	19	145
MILL CREEK	1453	$132,109,061.92	1289	122	4	37	559
MUDDY FORK BEARGRASS CREEK	235	$61,036,040.00	208	11	0	16	181
PENNSYLVANIA RUN	53	$5,074,145.00	52	0	0	1	8
POND CREEK	5905	$603,635,087.04	3988	1646	146	116	919
SOUTH FORK BEARGRASS CREEK	1857	$225,002,436.33	1339	380	36	99	553
TOTALS	**10,959**	**$1,402,425,634.21**	**7,873**	**2,399**	**243**	**430**	**2,693**

3.7.2.4 Natural and Beneficial Floodplain Functions

The table below identifies key natural and beneficiary functions located in each watershed. This data showcases areas that need to be preserved and maintained in order to mitigate the effects of the flood risk. The following variables provide unique, natural habitats and are considered beneficial based on their ability to remove water pollutants and to store floodwaters during flood events.

Natural and Beneficial Floodplain Functions

Along with flood protection and floodplain management, mitigation plans *should* discuss the unique natural features, natural areas, and other environmental and aesthetic attributes that may be present in the floodplain.

Protecting and preserving these natural and beneficial floodplain functions yield flood mitigation benefits and also help integrate floodplain management efforts with other community goals and objectives.

NATURAL AND BENEFICIAL FUNCTIONS IN THE WATERSHEDS	Hydric Soil %	Open Space %	Regulatory Floodplain %	Combined Sewer Draft %	Wetland %
CEDAR CREEK	3.37	2.61	4.20	0.00	0.98
CITY/OHIO RIVER	1.10	7.59	14.56	6.40	1.48
FLOYDS FORK	0.78	2.39	10.40	0.00	1.44
GOOSE CREEK	2.51	4.60	8.55	0.00	0.73
HARRODS CREEK	1.88	15.99	7.67	0.00	1.53
MIDDLE FORK BEARGRASS CREEK	0.30	12.29	7.81	0.00	0.36
MILL CREEK	6.27	3.66	10.49	0.18	1.52
MUDDY FORK BEARGRASS CREEK	1.12	4.66	14.33	0.00	0.31
PENNSYLVANIA RUN	3.59	6.68	5.31	0.00	1.75
POND CREEK	13.70	3.52	18.95	0.00	1.96
SOUTH FORK BEARGRASS CREEK	1.10	19.17	10.72	0.08	0.23

3.7.2.5 Critical Facilities in a Floodplain

Critical Facilities are essential to the health and welfare of the whole population and are especially important following hazard events. The table below identifies existing critical facilities located in the Regulatory Floodplain. The following variables were used in the Exposure Score. The identification of these properties provide prime locations for hazard mitigation project opportunities and also identify potential health and safety problems caused by disaster, such as when the sewer treatment plant is flooded.

Existing Critical Facilities located in the Regulatory Floodplain

WATERSHEDS	Nursing Home	Daycare	EMS	Hospital	EOP	Suburban Fire	Louisville Fire	Police	Schools	University	Govt. Buildings	Siren	Airport	HAZ/MAT	Sewer Pump Station	Sewer Treatment	LWC Sites	Electric Substation
CEDAR CREEK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
CITY/OHIO RIVER	0	0	0	0	0	1	0	0	0	0	3	2	0	20	1	0	1	4
FLOYDS FORK	0	0	0	0	0	0	0	0	0	0	0	1	0	8	0	3	0	0
GOOSE CREEK	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	6	0	0
HARRODS CREEK	0	0	0	0	0	0	0	1	0	0	1	0	0	2	0	1	0	0
MIDDLE FORK BEARGRASS CREEK	2	1	0	0	0	0	0	0	0	0	0	0	0	18	0	1	0	1
MILL CREEK	1	4	0	0	0	2	0	0	1	0	0	3	0	7	2	2	0	1
MUDDY FORK BEARGRASS CREEK	0	1	0	0	0	0	0	1	0	2	0	1	0	3	0	1	0	0
PENNSYLVANIA RUN	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	4	0	0
POND CREEK	1	13	0	0	1	1	0	0	4	1	3	6	0	90	0	21	0	4
SOUTH FORK BEARGRASS CREEK	2	8	0	0	0	0	1	0	4	0	3	3	0	24	0	0	0	0
TOTALS	**6**	**27**	**0**	**0**	**1**	**4**	**1**	**2**	**9**	**3**	**10**	**16**	**0**	**178**	**3**	**41**	**1**	**10**

3.7.3 Watershed Overviews

3.7.3.1 Ohio River/City Watershed

The Ohio River Watershed has an area of approximately 39.8 square miles and contains 49.5 stream miles, most of which are the Main Stem of the Ohio River. This watershed is drained by a complex system of combined sewers. No open channels of any magnitude exist.

The Ohio River Main Stem through Louisville Metro is located along the northwestern border of Jefferson County and the far side of the river is in Indiana. A levee and floodwall system separates the river from the rest of Louisville Metro. The flood protection system includes pump stations and dams at all stream crossings and combined sewer overflows (CSO) outfalls.

Communities situated in this watershed include downtown Louisville, Kenwood, Southern Heights, Beechmont, Oakdale, Wilder Park, Parkland, South Parkland, Shawnee, and Portland. Notable landmarks include the Kentucky Fair and Exposition Center, the University of Louisville, Churchill Downs, Kentucky International Convention Center, City Hall, portions of Iroquois Park, Shawnee Park, and Chickasaw Park.

Many other parks are located along the Ohio River and provide preserved open space along the Ohio River floodplain. These parks include Eva Bandman Park, Capertown Swamp, Chickasaw Park, Carrie Gaulbert Cox Park, Hays Kennedy Park, Kulmer Reserve, Lannan Park, Portland Wharf Park, Riverside Farnsley-Moorman Landing, Riverview Park, Thurman Hutchins Park, Twin Park, and Waterfront Park.

Ohio River and Floodwall

A large portion of Louisville Metro lies within the broad floodplain of the Ohio River; however, about 17,600 acres of this floodplain, including downtown Louisville, are protected by a 28.9 mile long flood protection system. The first phase of the system, which protects the area from Beargrass Creek to just south of Rubbertown, was completed by the Army Corps of Engineers in 1957. A second phase was completed in the late 1980s to protect southwest Louisville Metro, from Rubbertown to Pond Creek. The floodwall system is built to protect Louisville Metro from floods equivalent to the historic flood event of 1937 with three feet of freeboard.

Topography

The major portion of the Ohio River/City Watershed is located in the Flood Plain Topographic Region. The remaining portion lies in the Central Basin. A very flat, low-lying terrain predominates both the Flood Plain and Central Basin Regions. Elevations range from about 382 feet, the pool stage of the Ohio River below the McAlpine Lock and Dam, to about 586 feet in Glenview.

Existing Structural Flood Controls

No open channels of any magnitude exist in this watershed; however, in order to help reduce combined sewer overflows, there are two regional detentions basins located in the Ohio River/City Watershed. These basins are Executive Inn Basin and Brady Lake.

Basic Watershed Flood Information

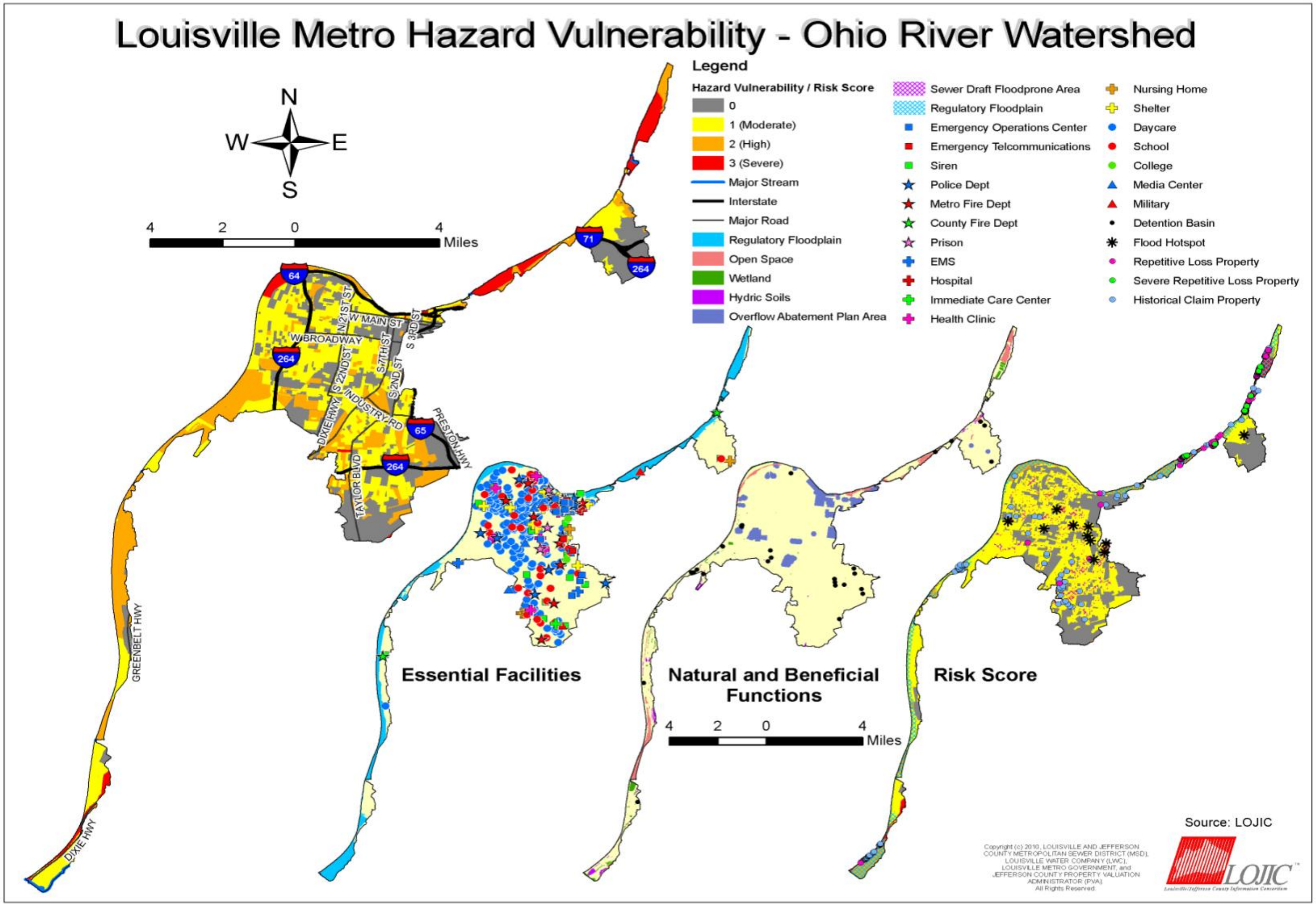
Depth of Water: Using the Flood Insurance Study (FIS) Flood Profile data for the Ohio River the mean average depth of flooding from the stream bed to the Regulatory Floodplain is 80.8 feet. This data was derived from 35 cross sections on the Ohio River.

Velocities: Using the FIS Flood Profile data (Floodway) for the Ohio River the mean average velocity is 4.9 feet per second. This data was derived from 35 cross sections on the Ohio River.

Note: The above information is a mean average for the flooding source. Specific locations will provide different outputs throughout the watershed. It should be noted that we can calculate a depth at any point within the floodplain by comparing the ground elevation from the digital terrain model to the flood elevation layer where data permits.

The following map depicts the Ohio River/City Watershed Vulnerability Score map, which based on the same model. This map details areas of high vulnerability based on several different factors such as: Regulatory Floodplain, “Draft” Combined Sewer Floodprone Area study, Repetitive Loss Properties, Severe Repetitive Loss, Historical Claims data and Flood Hotspot data. These variables provide a detailed Risk Score that displays areas at risk based on mapped floodplains and mapped occurrence hotspots.

These two factors provide Louisville Metro with a comprehensive understanding of where flooding is occurring and potentially causing damage. In addition the following maps display the essential facilities and the natural and beneficial functions for open space and wetlands locations.


Louisville Metro Hazard Vulnerability - Ohio River Watershed
Legend
Hazard Vulnerability / Risk Score
0
1 (Moderate)
2 (High)
3 (Severe)
Major Stream
Interstate
Major Road
Regulatory Floodplain
Open Space
Wetland
Hydric Soils
Overflow Abatement Plan Area
Sewer Draft Floodprone Area
Regulatory Floodplain
Emergency Operations Center
Emergency Telcommunications
Siren
Police Dept
Metro Fire Dept
County Fire Dept
Prison
EMS
Hospital
Immediate Care Center
Health Clinic
Nursing Home
Shelter
Daycare
School
College
Media Center
Military
Detention Basin
Flood Hotspot
Repetitive Loss Property
Severe Repetitive Loss Property
Historical Claim Property
N
W
E
S
4 2 0 4 Miles
W MAIN ST
W BROADWAY
DIXIE HWY
INDUSTRY RD
PRESTON HWY
TAYLOR BLVD
GREENBELT HWY
DIXIE HWY
Essential Facilities
Natural and Beneficial Functions
Risk Score
4 2 0 4 Miles
Source: LOJIC
LOJIC

3.7.3.2 Middle Fork Watershed – Beargrass Creek

The Middle Fork of Beargrass Creek Watershed is located in the north central portion of Louisville Metro and covers about 25 square miles. The headwaters originate in Middletown and flow in a westerly direction through St. Matthews. The stream continues into the Highlands via Seneca and Cherokee Parks, to finally outlet into the South Fork Beargrass Creek just south of Main Street.

The Middle Fork headwaters runs through residential neighborhoods, apartment and condominium complexes, three golf courses, a farm, two shopping malls, two parks in St. Matthews, and past hospitals and shopping centers. The creek parallels I-64 as it passes through Seneca Park, flows on down through Cherokee Park and beside a well-traveled greenway where it converges with the South Fork then the Muddy Fork of Beargrass Creek. The Middle Fork is the least-modified of the urban streams, has a bedrock or stone bed with riffles and pools in the Olmsted parks and is fed by small groundwater springs for much of the year.

The major streams in the Middle Fork Beargrass Creek Watershed are Middle Fork and Weicher Creek. Communities lying in this watershed include the Highlands, Seneca Gardens, St. Regis Park, St. Matthews, Lyndon, Wildwood, Hurstbourne, Douglass Hills, and Middletown. Notable landmarks include Cherokee Park, Seneca Park, Cave Hill Cemetery, the Southern Baptist Seminary, Bowman Field, Big Spring Country Club, Oxmoor Mall, and Hurstbourne Country Club.

Several parks are located along the Middle Fork of Beargrass Creek. These parks provide open space where flooding can occur without property damages and allow recreational use during drier periods. Cherokee Park, owned by the Louisville Metro, is located along Middle Fork Beargrass Creek in the Highlands area. The City of St. Matthews owns two parks, Brown Park and Arthur K. Draut Park, located in the floodplain along Middle Fork of Beargrass Creek near Bowling Boulevard. The Draut Park includes wetlands, which help improve the natural and beneficial functions of the floodplains as well as water quality for the creek.

Wetlands located along Middle Fork Beargrass Creek at Arthur K. Draut Park

Topography

The entire Middle Fork Beargrass Creek Watershed is situated in the Eastern Uplands Topographic Region. Broad steep-sided valleys and flat to gently rolling plateaus dominate the terrain. Middle Fork Beargrass Creek has cut deeply into this terrain and flows through a well entrenched channel where near vertical cliffs are common. Elevations range from about 425 feet, at the confluence with South Fork Beargrass Creek, to about 750 feet, in the Middletown area.

Existing Structural Flood Controls

The Whipps Mill Basin is a regional flood storage basin that is situated in the upper portion of the Middle Fork Watershed. The basin, which was built in 2000, covers a 40-acre site and provides flood protection for hundreds of residents. The Woodlawn Park Basin is another regional basin located in the Middle Fork Watershed.

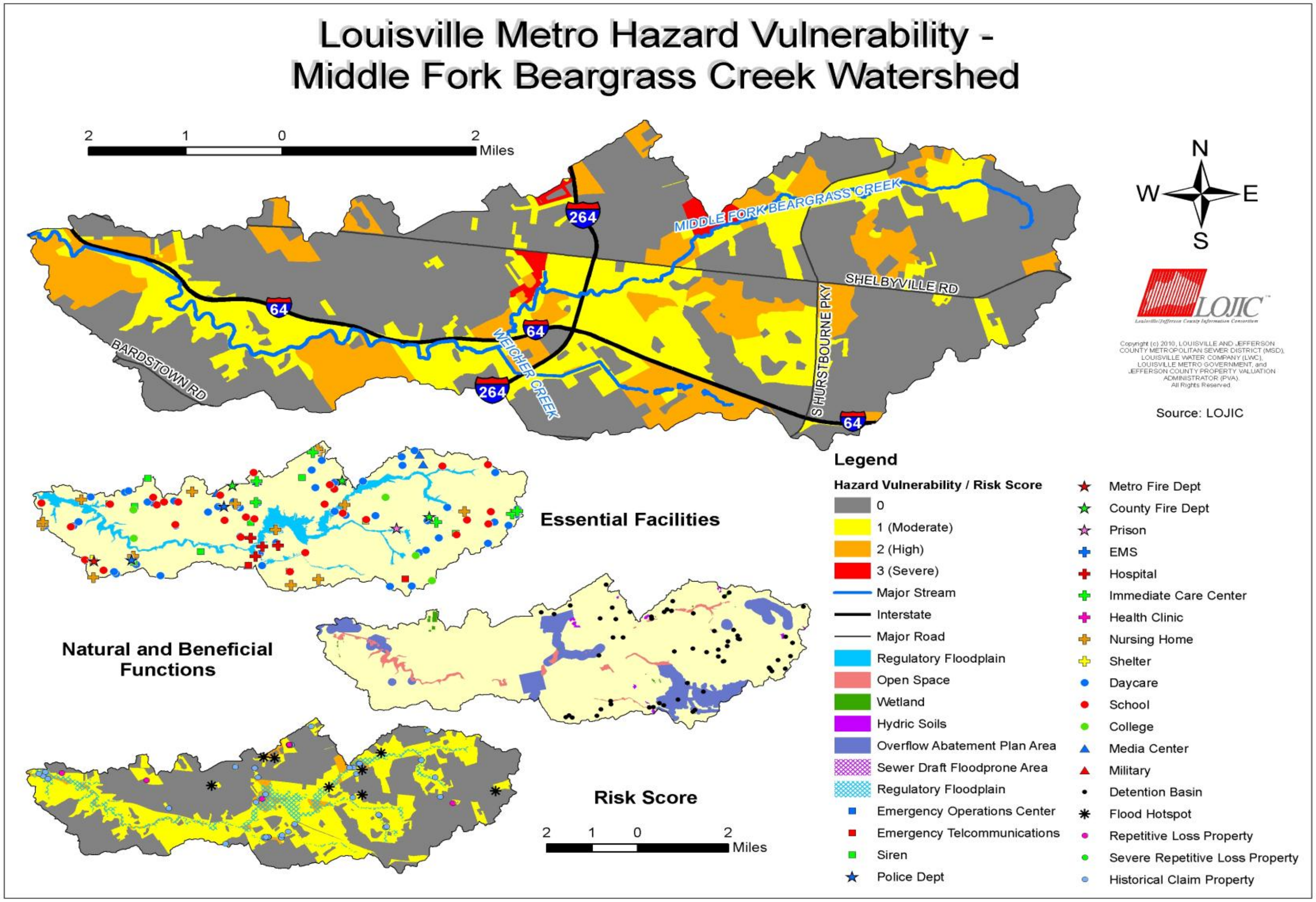
Basic Watershed Flood Information

Depth of Water: Using the FIS Flood Profile data for Middle Fork Beargrass Creek the mean average depth of flooding from the stream bed to the Regulatory Floodplain is 13.2 feet. This data was derived from 60 cross sections on Middle Fork Beargrass Creek. Using the FIS Flood Profile data for Weicher Creek the mean average depth of flooding from the stream bed to the Regulatory Floodplain is 5.4 feet. This data was derived from 30 cross sections on Weicher Creek.

Velocities: Using the FIS Flood Profile data (Floodway) for Middle Fork Beargrass Creek the mean average velocity is 4.9 feet per second. This data was derived from 60 cross sections on the Middle Fork Beargrass Creek. Using the FIS Flood Profile data (Floodway) for Weicher Creek the mean average velocity is 3.8 feet per second. This data was derived from 30 cross sections on Weicher Creek.

Note: The above information is a mean average for the flooding source. Specific locations will provide different outputs throughout the watershed. It should be noted that we can calculate a depth at any point within the floodplain by comparing the ground elevation from the digital terrain model to the flood elevation layer where data permits.

The following map depicts the Middle Fork Beargrass Creek Watershed Vulnerability Score map. This map details areas of high vulnerability based on several different factors such as: Regulatory Floodplain, Repetitive Loss Properties, Severe Repetitive Loss Properties, Historical Claims data, and Flood Hotspot data. These variables provide a detailed Risk Score that displays areas at risk based on mapped floodplains and mapped occurrence hotspots. These two factors provide Louisville Metro with a comprehensive understanding of where flooding is occurring and potentially causing damage. In addition the map displays the essential facilities and the natural and beneficial function locations.


Louisville Metro Hazard Vulnerability -
Middle Fork Beargrass Creek Watershed
2 1 0 2 Miles
MIDDLE FORK BEARGRASS CREEK
SHELBYVILLE RD
S HURSTBOURNE PKY
BARDSTOWN RD
WEICHER CREEK
264
64
N
W
E
S
LOJIC
Source: LOJIC
Essential Facilities
Natural and Beneficial Functions
Risk Score
2 1 0 2 Miles
Legend
Hazard Vulnerability / Risk Score
0
1 (Moderate)
2 (High)
3 (Severe)
Major Stream
Interstate
Major Road
Regulatory Floodplain
Open Space
Wetland
Hydric Soils
Overflow Abatement Plan Area
Sewer Draft Floodprone Area
Regulatory Floodplain
Emergency Operations Center
Emergency Telcommunications
Siren
Police Dept
Metro Fire Dept
County Fire Dept
Prison
EMS
Hospital
Immediate Care Center
Health Clinic
Nursing Home
Shelter
Daycare
School
College
Media Center
Military
Detention Basin
Flood Hotspot
Repetitive Loss Property
Severe Repetitive Loss Property
Historical Claim Property

3.7.3.3 Muddy Fork Watershed – Beargrass Creek

The eight square mile Muddy Fork Beargrass Creek Watershed is located in the north central portion of Louisville Metro including Indian Hills and a small part of St. Matthews. Its headwaters originate in the Graymoor/Devondale area. After descending from Indian Hills, Muddy Fork runs parallel to I-71 in the Ohio River floodplain, converging with the Main stem of Beargrass Creek before emptying into the river. Muddy Fork regularly receives backwater from the Ohio River.

Communities lying in this watershed include Graymoor, Devondale, Crescent Hill, Rolling Fields, Mockingbird Valley, Indian Hills, and Windy Hills. Notable landmarks include the VA Hospital, Crescent Hill Park, and the Louisville County Club.

Topography

The major portion of the Muddy Fork Watershed is situated in the Eastern Uplands Topographic Region. Broad steep-sided valleys and gently rolling plateaus dominate the terrain in the Eastern Uplands Region. Muddy Fork has cut deeply into this terrain and flows though a well entrenched channel where near vertical cliffs are common.

The remaining portion, which includes I-71 and land adjacent to the Ohio River, is in the Flood Plain. A flat, low-lying terrain predominates in the floodplain. Stream channels of low gradient slopes tend to parallel the Ohio River. Elevations range from about 420 feet, the pool stage of the Ohio River above the McAlpine Lock and Dam, to about 585 feet, in the Devondale area.

Existing Structural Flood Controls

No regional basins or major channel improvement projects are located in the Muddy Fork Watershed.

Basic Watershed Flood Information

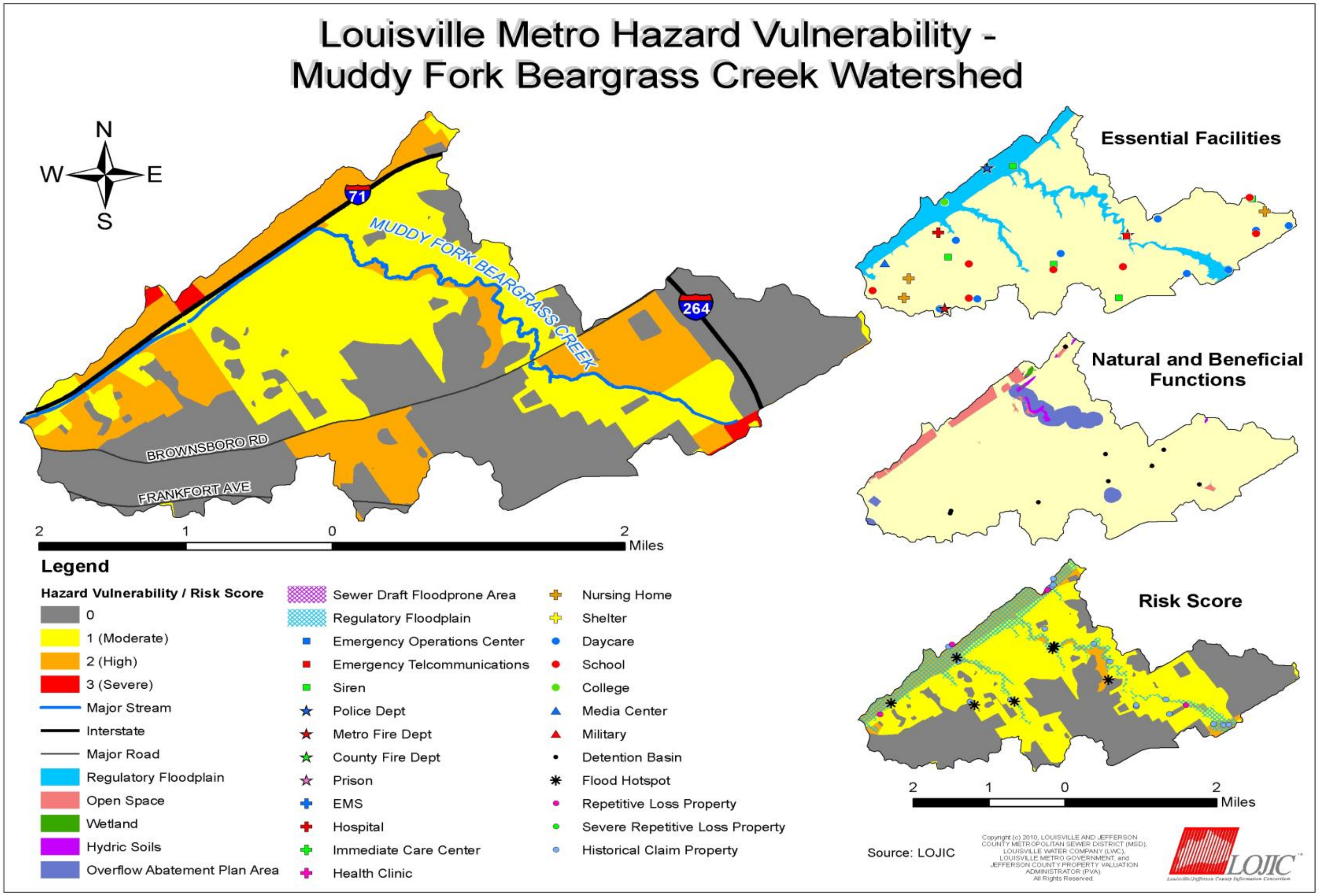
Depth of Water: Currently there is no data that displays depth of water for the Muddy Fork Beargrass Creek watershed. This will be addressed in our 2010 RiskMAP update.

Velocities: Currently there is no data that displays velocities for the Muddy Fork Beargrass Creek watershed. This will be addressed in our 2010 RiskMAP update.

Note: The above information is a mean average for the flooding source. Specific locations will provide different outputs throughout the watershed. It should be noted that we can calculate a depth at any point within the floodplain by comparing the ground elevation from the digital terrain model to the flood elevation layer where data permits.

The following map depicts the Muddy Fork Beargrass Creek Watershed Vulnerability Score map. This map details areas of high vulnerability based on several different factors such as: Regulatory Floodplain, Repetitive Loss Properties, Severe Repetitive Loss Properties, Historical

Claims data and Flood Hotspot data. These variables provide a detailed Risk Score that displays areas at risk based on mapped floodplains and mapped occurrence hotspots. These two factors provide Louisville Metro with a comprehensive understanding of where flooding is occurring and potentially causing damage. In addition the map displays the essential facilities and the natural and beneficial function locations.


Louisville Metro Hazard Vulnerability -
Muddy Fork Beargrass Creek Watershed
N
W
E
S
71
264
MUDDY FORK BEARGRASS CREEK
BROWNSBORO RD
FRANKFORT AVE
2 1 0 2 Miles
Essential Facilities
Natural and Beneficial Functions
Risk Score
2 1 0 2 Miles
Legend
Hazard Vulnerability / Risk Score
0
1 (Moderate)
2 (High)
3 (Severe)
Major Stream
Interstate
Major Road
Regulatory Floodplain
Open Space
Wetland
Hydric Soils
Overflow Abatement Plan Area
Sewer Draft Floodprone Area
Regulatory Floodplain
Emergency Operations Center
Emergency Telcommunications
Siren
Police Dept
Metro Fire Dept
County Fire Dept
Prison
EMS
Hospital
Immediate Care Center
Health Clinic
Nursing Home
Shelter
Daycare
School
College
Media Center
Military
Detention Basin
Flood Hotspot
Repetitive Loss Property
Severe Repetitive Loss Property
Historical Claim Property
Source: LOJIC
Copyright (c) 2010, LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT (MSD), LOUISVILLE WATER COMPANY (LWC), LOUISVILLE METRO GOVERNMENT, and JEFFERSON COUNTY PROPERTY VALUATION ADMINISTRATOR (PVA). All Rights Reserved.
LOJIC

3.7.3.4 South Fork Watershed – Beargrass Creek

The 27 square mile South Fork Beargrass Creek Watershed is located in the north central portion of Louisville Metro. Headwaters originate in Jeffersontown and eventually outlet into the Ohio River near Towhead Island. At about mile 0.75 of South Fork, the Louisville Local Flood Protection Project (Floodwall) crosses the stream. The Beargrass Pumping Station is located at this point.

From approximately mile 1.4 to mile 4.1, the stream is a large concrete channel with high vertical sidewalls. Major streams in this watershed include South Fork Beargrass Creek and Buechel Branch.

The South Fork drains a significant area of residential and institutional properties, parklands, and cemeteries where it flows in a straightened canal between Newburg Road and Poplar Level Road. At Eastern Parkway, South Fork enters the concrete “improved channel” and flows toward downtown Louisville where it joins Middle Fork and becomes the Main Stem.

Some tributaries in older portions of town such as Snead’s Branch and the tributary along and under Trevilian Way were enclosed in pipes and converted into sewers during the booming suburban development of the 1890s-1920s. A cave along the creek bank is the only known home of the Louisville Cave Beetle, an endemic species that is listed as a Candidate for endangered species status.

Beargrass Creek Flood Pumping Station

Communities lying in the watershed include Jeffersontown, Phoenix Hill, Germantown, Audubon Park, Strathmoor, Wellington, Buechel, Highgate Springs, Houston Acres, Forest Hills, Schnitzelburg, Smoketown, Shelby Park, Tyler Park, and the Highlands. Notable landmarks include the Beargrass Creek Pumping Station, Calvary Cemetery, the Louisville Zoo, Tyler Park, and Rest Haven Memorial Cemetery. Several parks are located within the floodplain of South Fork Beargrass Creek, including Joe Creason Park and the Beargrass Creek State Nature Preserve. Buechel Park is located along Buechel Branch, a tributary of South Fork Beargrass Creek. These parks provide open space where flooding can occur without property damage, as well as recreational uses during drier periods.

Topography

The major portion of the South Fork Beargrass Creek Watershed is situated in the Eastern Uplands Topographic Region. Broad steep-sided valleys and flat to gently rolling plateaus dominate the terrain in the Uplands Region. South Fork Beargrass Creek has cut deeply into this terrain and flows through a well entrenched channel.

The remaining portion, which lies west of the Louisville and Nashville Railroad and adjacent to the Ohio River, is in the Flood Plain. A very flat, low-lying terrain predominates in the Flood Plain. South Fork Beargrass Creek flows through an improved concrete channel in this region. Elevations range from about 420 feet, the pool stage of the Ohio River above McAlpine Lock and Dam, to about 690 feet, in the area north of Jeffersontown.

Existing Structural Flood Controls

The South Fork Beargrass Creek Flood Protection project was initiated in 2001 and is currently in the final stages of completion. The project was a joint project between the Army Corps of Engineers and MSD and included the construction of eight regional basins, ranging in size from 9 acre-feet to 160 acre-feet of storage, throughout the South Fork Watershed. The project also included 2000 feet of channel improvement, 1900 feet of floodwall around an apartment complex, and environmental features, such as construction of pools and riffles in the channels and planting 9 acres of bottomland hardwoods. The purpose of the project was to help relieve flooding in the South Fork Watershed. The basins are located near Bashford Manor, Breckenridge Lane, Downing Way, Fountain Square, Hikes Lane, Gerald Court, Richlawn Ave, and Old Shepherdsville Road. Another regional basin, the Dry Bed Reservoir, is also located in the South Fork Beargrass Creek Watershed. This basin was constructed in the 1970s to relieve flooding along South Fork.

Basic Watershed Flood Information

Depth of Water:

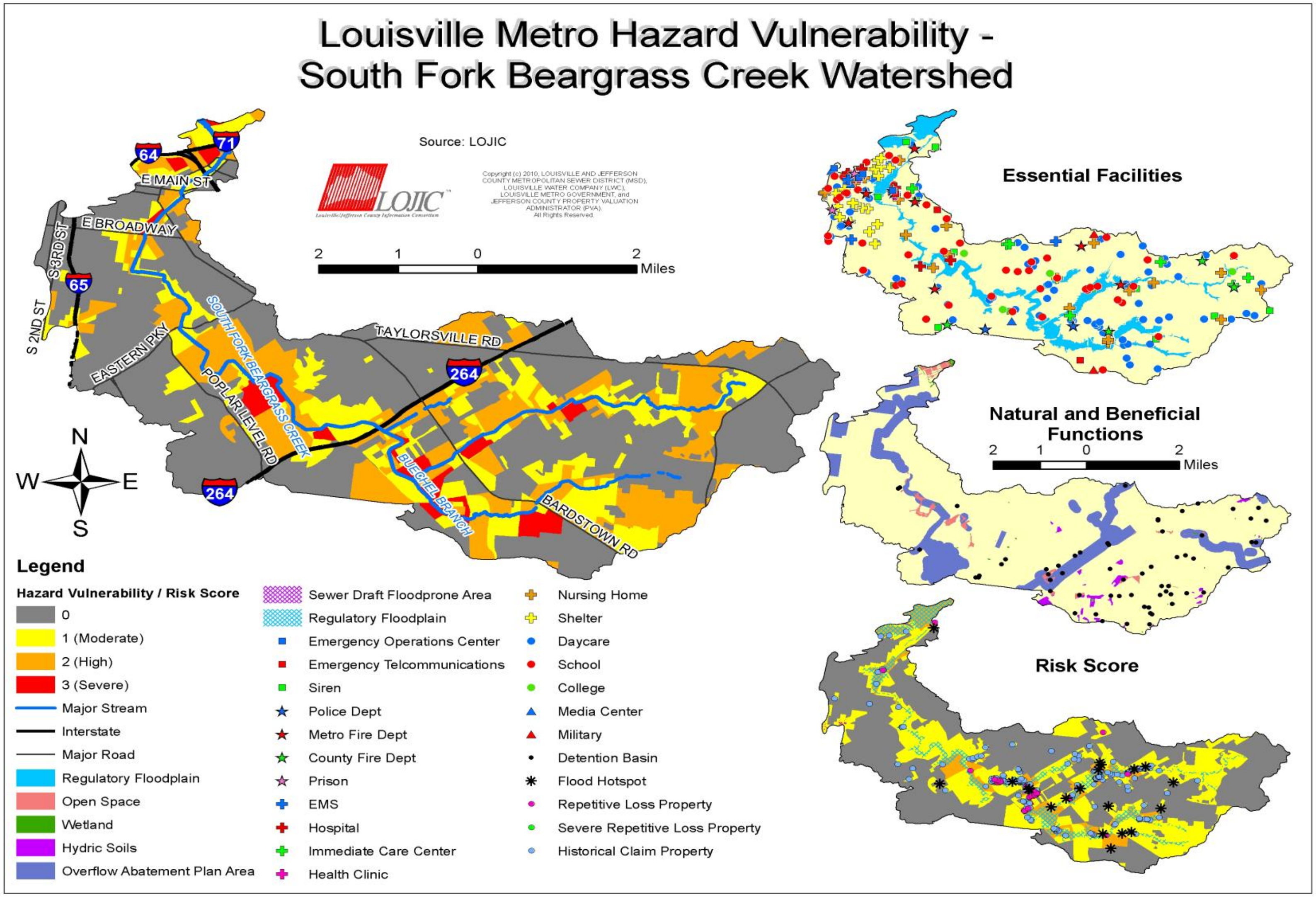
- Using the FIS Flood Profile data for South Fork Beargrass Creek the mean average depth of flooding from the stream bed to the Regulatory Floodplain is 14.6 feet. This data was derived from 80 cross sections on South Fork Beargrass Creek.
- Using the FIS Flood Profile data for Buechel Branch the mean average depth of flooding from the stream bed to the Regulatory Floodplain is 9.9 feet. This data was derived from 9 cross sections on Buechel Branch.

Velocities:

- Using the FIS Flood Profile data (Floodway) for South Fork Beargrass Creek the mean average velocity is 5.0 feet per second. This data was derived from 80 cross sections on the South Fork Beargrass Creek.
- Using the FIS Flood Profile data (Floodway) for Buechel Branch the mean average velocity is 3.4 feet per second. This data was derived from 9 cross sections on Buechel Branch.

Note: The above information is a mean average for the flooding source. Specific locations will provide different outputs throughout the watershed. It should be noted that we can calculate a depth at any point within the floodplain by comparing the ground elevation from the digital terrain model to the flood elevation layer where data permits.

The following map depicts the South Fork Beargrass Creek Watershed Vulnerability Score map. This map details areas of high vulnerability based on several different factors such as: Regulatory Floodplain, “Draft” Combined Sewer Floodprone Area study, Repetitive Loss Properties, Severe Repetitive Loss Properties, Historical Claims data, and Flood Hotspot data. These variables provide a detailed Risk Score that displays areas at risk based on mapped floodplains and mapped occurrence hotspots. These two factors provide Louisville Metro with a comprehensive understanding of where flooding is occurring and potentially causing damage. In addition the map displays the essential facilities and the natural and beneficial function locations.


Louisville Metro Hazard Vulnerability -
South Fork Beargrass Creek Watershed
Source: LOJIC
LOJIC
Copyright (c) 2010, LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT (MSD), LOUISVILLE WATER COMPANY (LWC), LOUISVILLE METRO GOVERNMENT, and JEFFERSON COUNTY PROPERTY VALUATION ADMINISTRATOR (PVA). All Rights Reserved.
2 1 0 2 Miles
64
71
E MAIN ST
E BROADWAY
S 3RD ST
65
S 2ND ST
EASTERN PKY
SOUTH FORK BEARGRASS CREEK
POPLAR LEVEL RD
TAYLORSVILLE RD
264
BUECHEL BRANCH
BARDSTOWN RD
N
W
E
S
Essential Facilities
Natural and Beneficial Functions
Risk Score
Legend
Hazard Vulnerability / Risk Score
0
1 (Moderate)
2 (High)
3 (Severe)
Major Stream
Interstate
Major Road
Regulatory Floodplain
Open Space
Wetland
Hydric Soils
Overflow Abatement Plan Area
Sewer Draft Floodprone Area
Regulatory Floodplain
Emergency Operations Center
Emergency Telcommunications
Siren
Police Dept
Metro Fire Dept
County Fire Dept
Prison
EMS
Hospital
Immediate Care Center
Health Clinic
Nursing Home
Shelter
Daycare
School
College
Media Center
Military
Detention Basin
Flood Hotspot
Repetitive Loss Property
Severe Repetitive Loss Property
Historical Claim Property

3.7.3.5 Cedar Creek Watershed

The 11 square mile Cedar Creek Watershed is located in south central Louisville Metro and contains 57.9 miles of streams. Its headwaters originate in the Fern Creek area. The stream flows in a southerly direction, passing into Bullitt County, and eventually discharges into Floyds Fork. Cedar Creek is the only major stream in this watershed.

Communities lying in this watershed include Fern Creek and Highview. Notable landmarks include Beulah Church and Fern Creek High School.

Also located in this watershed is the Cedar Creek Regional Wastewater Treatment Plant.

Topography

The entire Cedar Creek Watershed is situated in the Eastern Uplands Topographic Region. Broad, fairly steep-sided valleys and narrow ridge crests dominate the terrain. Streams have cut deeply into this terrain and flow through the well-entrenched channels. Elevations range from about 550 feet, at the Jefferson County/Bullitt line.

Existing Structural Flood Controls

The Cedar Creek Watershed has no regional basins or major channel improvement projects.

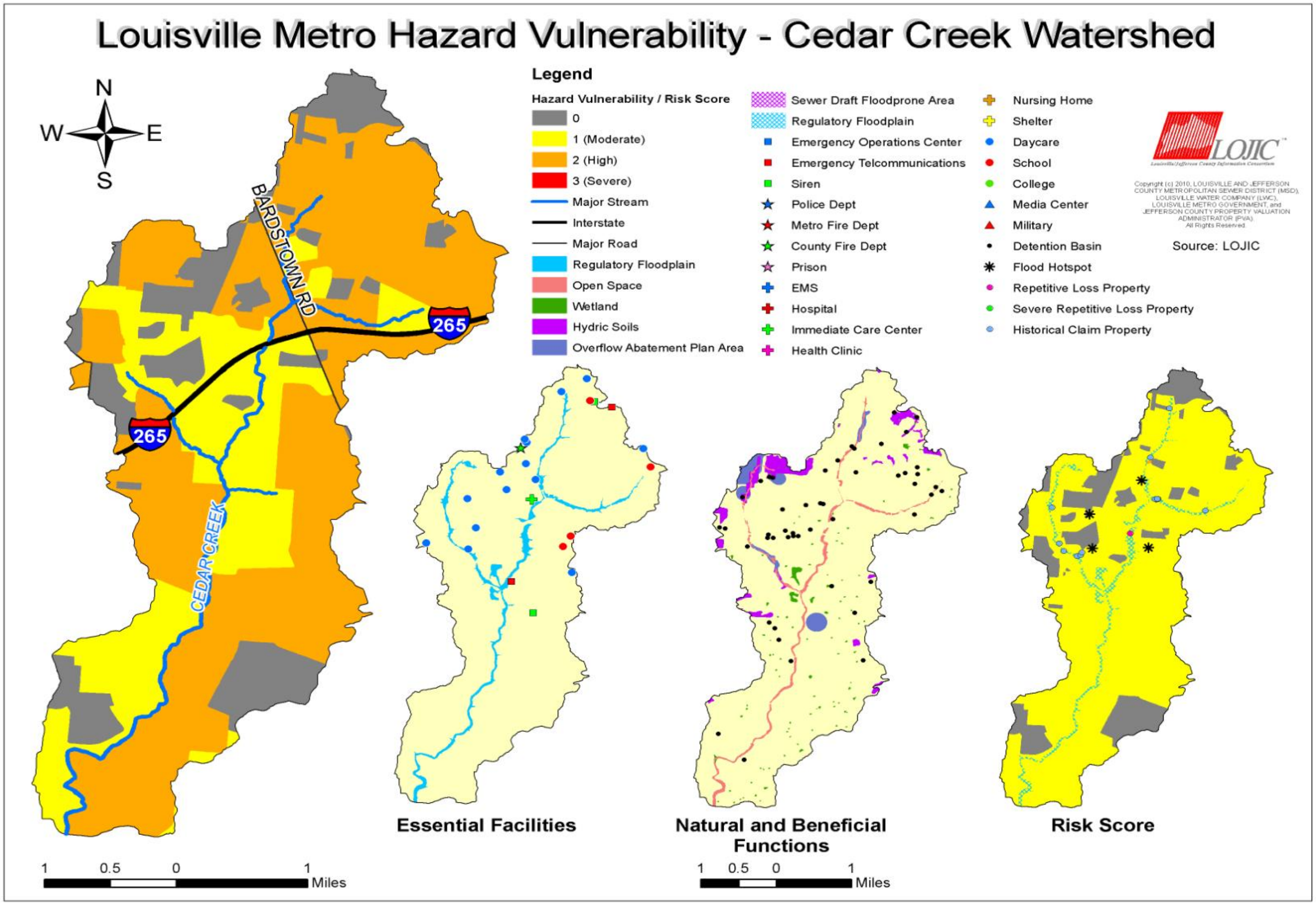
Basic Watershed Flood Information

Depth of Water: Using the FIS Flood Profile data for Cedar Creek the mean average depth of flooding from the stream bed to the Regulatory Floodplain is 23.5 feet. This data was derived from 20 cross sections on Cedar Creek.

Velocities: Currently there is no data that displays velocities for the Cedar Creek watershed.

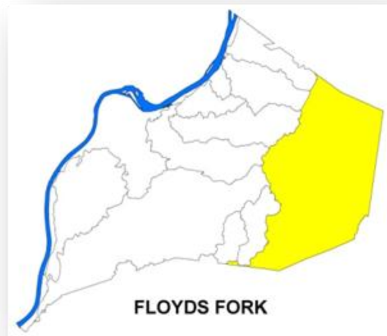
Note: The above information is a mean average for the flooding source. Specific locations will provide different outputs throughout the watershed. It should be noted that we can calculate a depth at any point within the floodplain by comparing the ground elevation from the digital terrain model to the flood elevation layer where data permits.

The following map depicts the Cedar Creek Watershed Vulnerability Score map. This map details areas of high vulnerability based on several different factors such as: Regulatory Floodplain, Repetitive Loss Properties, Severe Repetitive Loss Properties, Historical Claims data, and Flood Hotspot data. These variables provide a detailed Risk Score that displays areas at risk based on mapped floodplains and mapped occurrence hotspots. These two factors provide Louisville Metro with a comprehensive understanding of where flooding is occurring and potentially causing damage. In addition the map displays the essential facilities and the natural and beneficial function locations.


Louisville Metro Hazard Vulnerability - Cedar Creek Watershed
Legend
Hazard Vulnerability / Risk Score
0
1 (Moderate)
2 (High)
3 (Severe)
Major Stream
Interstate
Major Road
Regulatory Floodplain
Open Space
Wetland
Hydric Soils
Overflow Abatement Plan Area
Sewer Draft Floodprone Area
Regulatory Floodplain
Emergency Operations Center
Emergency Telcommunications
Siren
Police Dept
Metro Fire Dept
County Fire Dept
Prison
EMS
Hospital
Immediate Care Center
Health Clinic
Nursing Home
Shelter
Daycare
School
College
Media Center
Military
Detention Basin
Flood Hotspot
Repetitive Loss Property
Severe Repetitive Loss Property
Historical Claim Property
LOJIC
Source: LOJIC
N
W
E
S
BARDSTOWN RD
265
265
CEDAR CREEK
Essential Facilities
Natural and Beneficial Functions
Risk Score
1 0.5 0 1 Miles
1 0.5 0 1 Miles

3.7.3.6 Floyds Fork Watershed

The Floyds Fork Watershed is located in eastern Jefferson County, Henry, Oldham, Shelby, Spencer, and Bullitt Counties. Its headwaters originate in southwest Henry County, approximately 13 miles beyond the Louisville Metro boundary line. Flow is generally southwest through Oldham, Shelby, and Jefferson Counties, and then into Bullitt county, where it outlets into the Salt River. The major streams in this watershed are Floyds Fork, Pope Lick, and Chenoweth Run.



Floyds Fork is the largest watershed in Louisville Metro, covering approximately 103.9 square miles and containing 673.2 stream miles. Floyds Fork, which has a total watershed area of 460 square miles, originates in Trimble County (East Fork), and flows west through Oldham County and enters into Louisville Metro at Ash avenue.

Chenoweth Run is a tributary of Floyds Fork, which originates in the Middletown area and flows south and merging into Floyds Fork. The headwater portion of Chenoweth Run watershed is heavily developed.

Communities in the area include parts of Jeffersontown, Middletown, Anchorage, Berrytown, Woodland Hills, Tucker Station, and Hopewell. Notable landmarks include Fishermens Park, Chenoweth Park, Valhalla Golf Course, Midland Trail Golf Course, parts of Bluegrass Industrial Park, Eastern High School, and Jeffersontown High School. Existing parks along Floyds Fork include Floyds Fork Park and William F. Miles Park. Both of these parks provide open space that will be preserved along Floyds Fork.

The City of Parks, Future Fund, and 21st Century Parks are purchasing and preserving much of the floodplain along the creeks.

Topography

The watershed is situated in the Eastern Uplands Topographic Region. Broad, steep-sided valleys and narrow ridge crests dominate the terrain. Major streams have cut deeply into this terrain and flow through well-entrenched channels, where near-vertical cliffs are common. Elevations range from about 490, in the area of the Seatonville Springs Country Club, to about 760 feet, in the area north of Anchorage.

Existing Structural Flood Controls

There are no regional basins or major channel improvement projects located in the Floyds Fork Watershed.

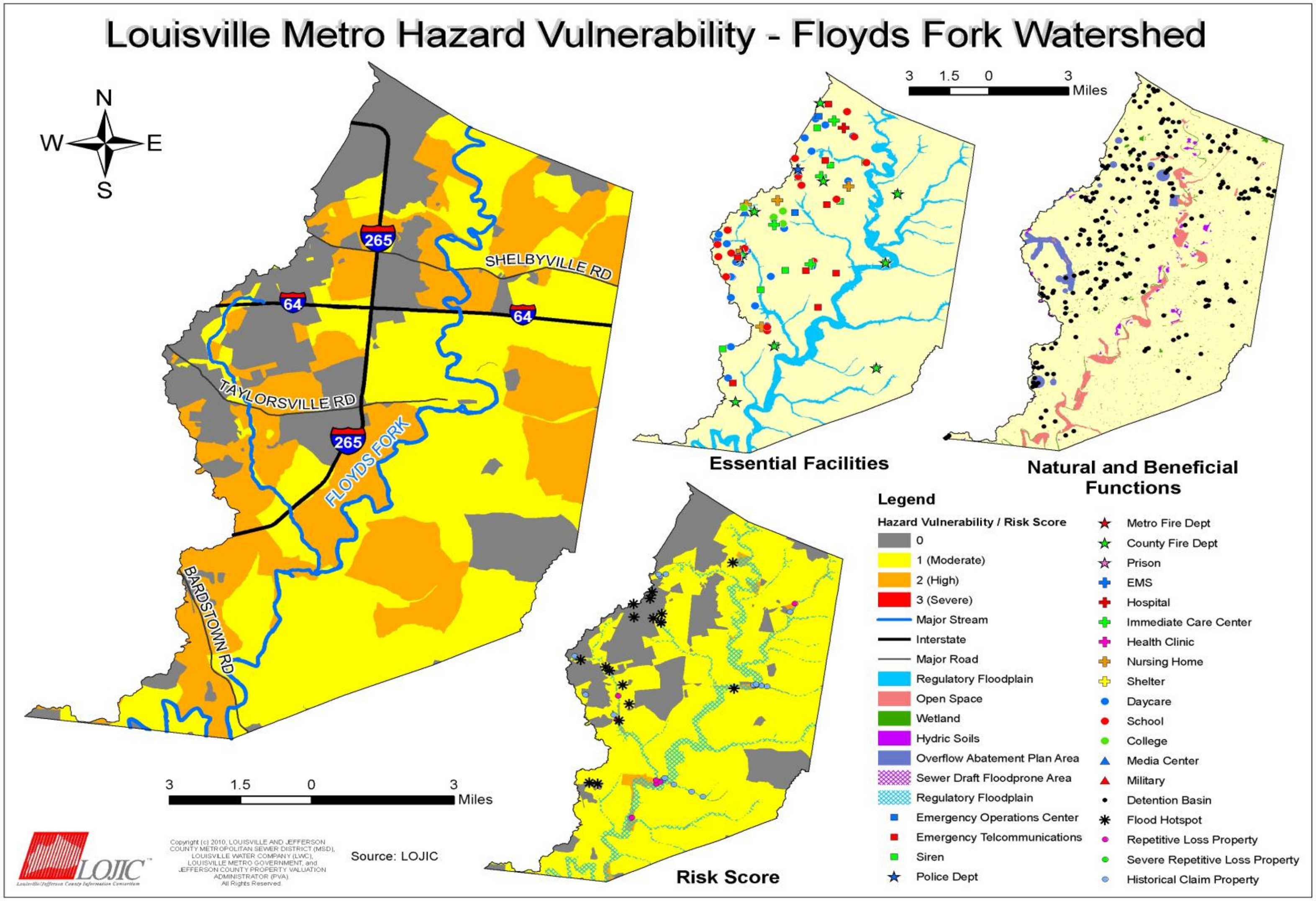
Basic Watershed Flood Information

Depth of Water: Using the FIS Flood Profile data for Floyds Fork the mean average depth of flooding from the stream bed to the Regulatory Floodplain is 22.3 feet. This data was derived from 51 cross sections on Floyds Fork.

Velocities: Using the FIS Flood Profile data (Floodway) for Floyds Fork the mean average velocity is 4.9 feet per second. This data was derived from 51 cross sections on the Floyds Fork.

Note: The above information is a mean average for the flooding source. Specific locations will provide different outputs throughout the watershed. It should be noted that we can calculate a depth at any point within the floodplain by comparing the ground elevation from the digital terrain model to the flood elevation layer where data permits.

The following map depicts the Floyds Fork Watershed Vulnerability Score map. This map details areas of high vulnerability based on several different factors such as: Regulatory Floodplain, Repetitive Loss Properties, Severe Repetitive Loss Properties, Historical Claims data and Flood Hotspot data. These variables provide a detailed Risk Score that displays areas at risk based on mapped floodplains and mapped occurrence hotspots. These two factors provide Louisville Metro with a comprehensive understanding of where flooding is occurring and potentially causing damage. In addition the map displays the essential facilities and the natural and beneficial function locations.


Louisville Metro Hazard Vulnerability - Floyds Fork Watershed
N
W
E
S
265
SHELBYVILLE RD
64
64
TAYLORSVILLE RD
265
FLOYDS FORK
BARDSTOWN RD
3 1.5 0 3 Miles
3 1.5 0 3 Miles
Essential Facilities
Natural and Beneficial Functions
Risk Score
Source: LOJIC
LOJIC
Legend
Hazard Vulnerability / Risk Score
0
1 (Moderate)
2 (High)
3 (Severe)
Major Stream
Interstate
Major Road
Regulatory Floodplain
Open Space
Wetland
Hydric Soils
Overflow Abatement Plan Area
Sewer Draft Floodprone Area
Regulatory Floodplain
Emergency Operations Center
Emergency Telcommunications
Siren
Police Dept
Metro Fire Dept
County Fire Dept
Prison
EMS
Hospital
Immediate Care Center
Health Clinic
Nursing Home
Shelter
Daycare
School
College
Media Center
Military
Detention Basin
Flood Hotspot
Repetitive Loss Property
Severe Repetitive Loss Property
Historical Claim Property

3.7.3.7 Goose Creek Watershed

The Goose Creek of the Ohio River Watershed has an area of approximately 18.5 square miles and contains Goose Creek of the Ohio River and Little Goose Creek of Goose Creek. The 18 square mile Goose Creek Watershed is located in northeastern Louisville Metro and is drained primarily by Goose Creek and Little Goose Creek.

- Goose Creek's headwaters originate in Anchorage, flow in a westerly direction to the area of Westport Middle School, then turn generally northwest, and finally outlet into the Ohio River at Six Mile Island.
- Little Goose Creek's headwaters originate in the Freys Hill area, flow northwesterly, and eventually discharge into Goose Creek about one-half mile from its outlet on the Ohio River.

Communities situated in this watershed include Anchorage, Rolling Hills, Plantation, Old Brownsboro Place, Hills and Dales, Glenview Heights, Brownsboro Farm, and Green Spring. Notable landmarks include Kentucky Country Day School, E.P. Tom Sawyer State Park, Owl Creek Country Club, Central State Hospital, Standard Country Club, and Ballard High School. Hounz Lane Park is located along Goose Creek and provides open space and wetland areas that will be preserved. E.P. "Tom" Sawyer State Park is another park located along Goose Creek that provides open space that will be preserved.

Topography

The major portion of the Goose Creek Watershed is situated in the Eastern Uplands Topographic Region. Broad, fairly steep-sided valleys and gently rolling plateaus dominate the terrain in the Uplands Region. Both Goose and Little Goose Creek have cut deeply into this terrain and they flow through well entrenched, channels, where near vertical cliffs are common.

The remaining portion, which lies adjacent to the Ohio River, is in the Flood Plain. A flat, low-lying terrain predominates in the Flood Plain Region. Excluding Goose Creek, stream channels of low gradient slopes tend to parallel the Ohio River. Elevations range from about 420 feet, the pool stage of the Ohio River at the McAlpine Lock and Dam, to about 760 feet, in the area north of Anchorage.

Existing Structural Flood Controls

There are no regional basins or major channel improvement projects located in the Goose Creek Watershed.

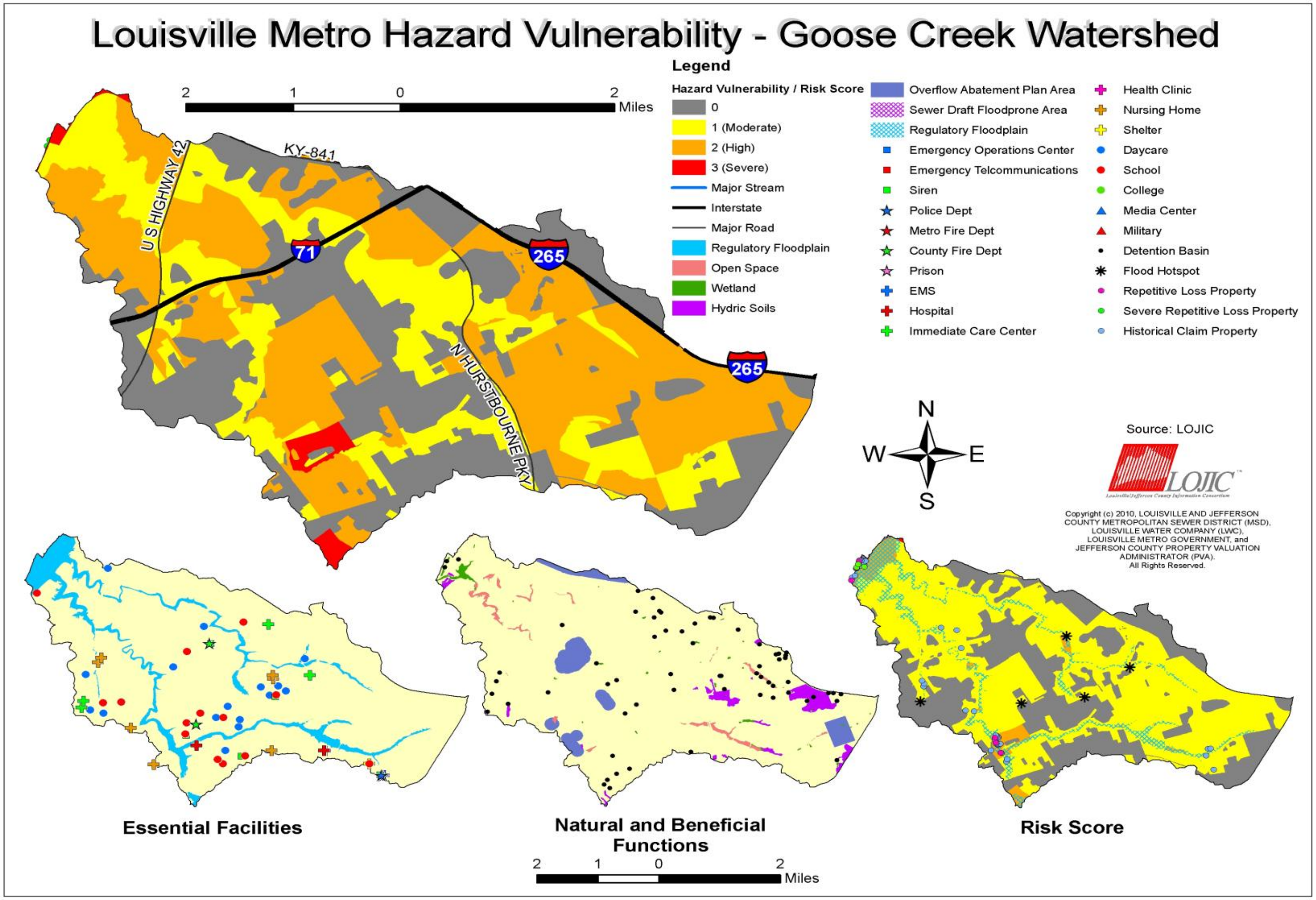
Basic Watershed Flood Information

Depth of Water: Using the FIS Flood Profile data for Goose Creek the mean average depth of flooding from the stream bed to the Regulatory Floodplain is 4.9 feet. This data was derived from 23 cross sections on Goose Creek.

Velocities: Using the FIS Flood Profile data (Floodway) for Goose Creek the mean average velocity is 4.7 feet per second. This data was derived from 23 cross sections on the Goose Creek.

Note: The above information is a mean average for the flooding source. Specific locations will provide different outputs throughout the watershed. It should be noted that we can calculate a depth at any point within the floodplain by comparing the ground elevation from the digital terrain model to the flood elevation layer where data permits.

The following map depicts the Goose Creek Watershed Vulnerability Score map. This map details areas of high vulnerability based on several different factors such as: Regulatory Floodplain, Repetitive Loss Properties, Severe Repetitive Loss Properties, Historical Claims data, and Flood Hotspot data. These variables provide a detailed Risk Score that displays areas at risk based on mapped floodplains and mapped occurrence hotspots. These two factors provide Louisville Metro with a comprehensive understanding of where flooding is occurring and potentially causing damage. In addition the map displays the essential facilities and the natural and beneficial function locations.


Louisville Metro Hazard Vulnerability - Goose Creek Watershed
Legend
Hazard Vulnerability / Risk Score
0
1 (Moderate)
2 (High)
3 (Severe)
Major Stream
Interstate
Major Road
Regulatory Floodplain
Open Space
Wetland
Hydric Soils
Overflow Abatement Plan Area
Sewer Draft Floodprone Area
Regulatory Floodplain
Emergency Operations Center
Emergency Telcommunications
Siren
Police Dept
Metro Fire Dept
County Fire Dept
Prison
EMS
Hospital
Immediate Care Center
Health Clinic
Nursing Home
Shelter
Daycare
School
College
Media Center
Military
Detention Basin
Flood Hotspot
Repetitive Loss Property
Severe Repetitive Loss Property
Historical Claim Property
2 1 0 2 Miles
KY-841
U S HIGHWAY 42
71
265
265
N HURSTBOURNE PKY
N
W
E
S
Source: LOJIC
LOJIC
Copyright (c) 2010, LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT (MSD), LOUISVILLE WATER COMPANY (LWC), LOUISVILLE METRO GOVERNMENT, and JEFFERSON COUNTY PROPERTY VALUATION ADMINISTRATOR (PVA). All Rights Reserved.
Essential Facilities
Natural and Beneficial Functions
Risk Score
2 1 0 2 Miles

3.7.3.8 Harrods Creek Watershed

The 180 square mile Harrods Creek Watershed is located in northeastern Jefferson County, Oldham, and Henry Counties. Its headwaters originate in the area east of LaGrange, KY, approximately 17 miles beyond the Jefferson County border. The creek flows generally to the southwest, converging with South Fork Harrods Creek about one-half mile outside the Louisville Metro line. From this point, the flow continues southwest through Louisville Metro to an outlet on the Ohio River at Guthrie Beach. Major streams in this watershed include Harrods Creek, Wolf Pen Branch, South Fork Harrods Creek, and South Fork Hite Creek.

Only 15.3 square miles of the Harrods Creek Watershed lies within Louisville Metro. Wolf Pen Branch, a tributary of Harrods Creek, originates in the Worthington area and flows northwest merging into Harrods Creek and eventually flowing into the Ohio River.

Communities in the study area include Fincastle, Ballardsville, Pewee Valley, Lake Louisvilla, Worthington, and Prospect. Notable landmarks include the Ford Motor Company Kentucky Truck Plant and Hunting Creek Country Club.

Topography

The major portion of the watershed is situated in the Eastern Uplands Topographic Region. The remaining portion lies adjacent to the Ohio River and is in the Flood Plain.

Broad steep-sided valleys and gently rolling plateaus dominate the terrain in the Uplands Region. Harrods Creek has cut deeply into this terrain and it flows through a well entrenched channel, where near-vertical cliffs are common. A very flat, low-lying terrain predominates in the Flood Plain, excluding Harrods Creek, stream channels of low gradient slopes tend to parallel the Ohio River. Elevations range from about 420 feet, the pool stage of the Ohio River above the McAlpine Lock and Dam, to about 780 feet, in an area southwest of Pewee Valley.

Outlet of Harrods Creek into the Ohio River

Existing Structural Flood Control

No regional basins or major channel improvement projects are located in the Harrods Creek Watershed.

Basic Watershed Flood Information

Depth of Water:

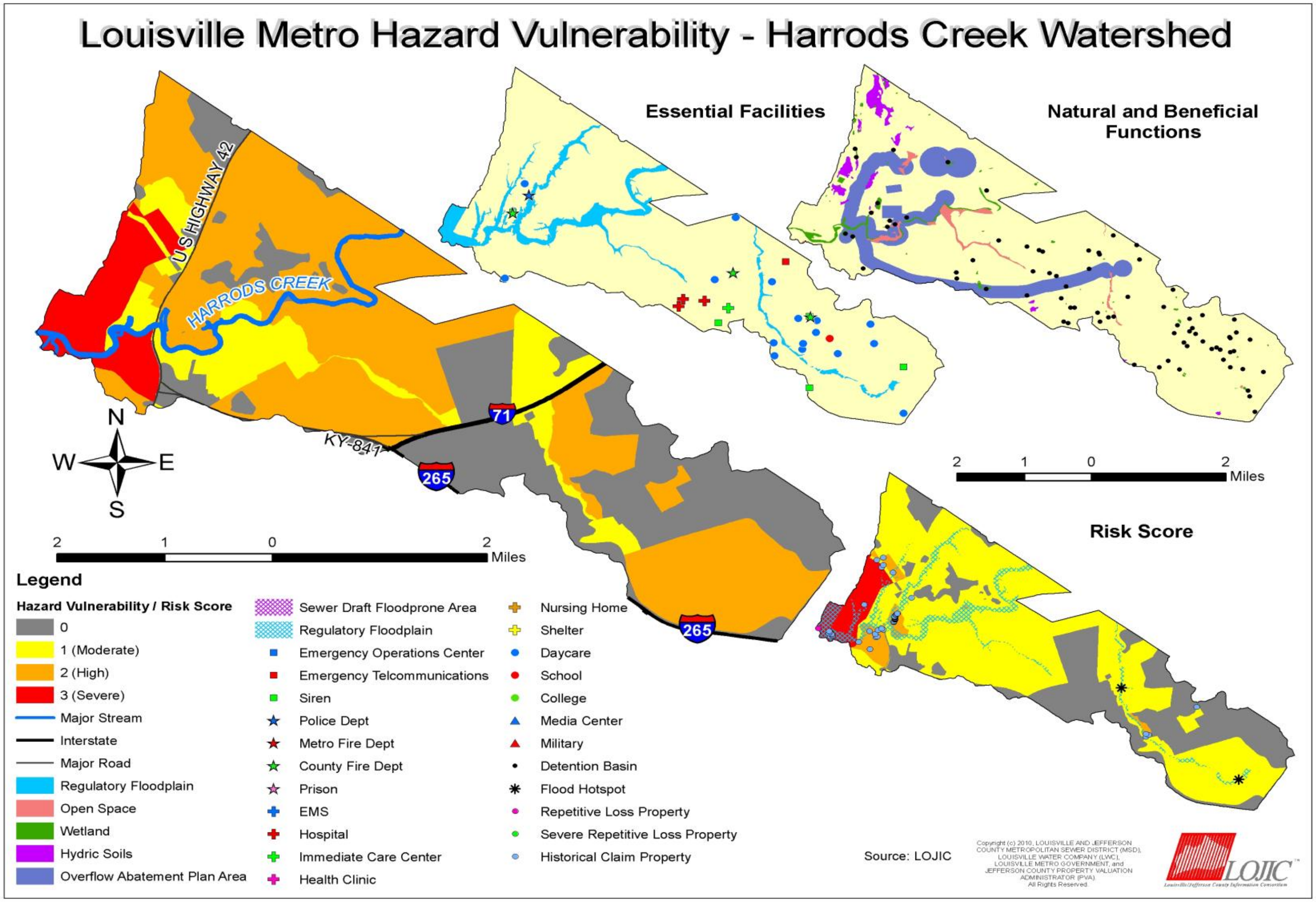
- Using the FIS Flood Profile data for Harrods Creek the mean average depth of flooding from the stream bed to the Regulatory Floodplain is 41 feet. This data was derived from 49 cross sections on Harrods Creek.
- Using the FIS Flood Profile data for South Fork Hite Creek the mean average depth of flooding from the stream bed to the Regulatory Floodplain is 8.2 feet. This data was derived from 39 cross sections on South Fork Hite Creek.

Velocities:

- Using the FIS Flood Profile data (Floodway) for Harrods Creek the mean average velocity is 7.3 feet per second. This data was derived from 49 cross sections on the Harrods Creek.
- Using the FIS Flood Profile data (Floodway) for South Fork Hite Creek the mean average velocity is 4.0 feet per second. This data was derived from 39 cross sections on the Harrods Creek.

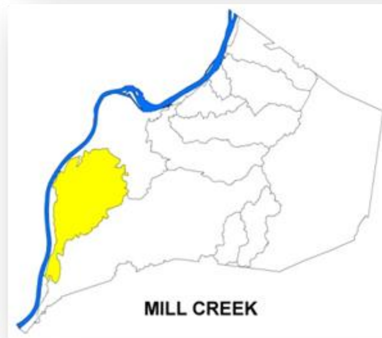
Note: The above information is a mean average for the flooding source. Specific locations will provide different outputs throughout the watershed. It should be noted that we can calculate a depth at any point within the floodplain by comparing the ground elevation from the digital terrain model to the flood elevation layer where data permits.

The following map depicts the Harrods Creek Watershed Vulnerability Score map. This map details areas of high vulnerability based on several different factors such as: Regulatory Floodplain, Repetitive Loss Properties, Severe Repetitive Loss Properties, Historical Claims data, and Flood Hotspot data. These variables provide a detailed Risk Score that displays areas at risk based on mapped floodplains and mapped occurrence hotspots. These two factors provide Louisville Metro with a comprehensive understanding of where flooding is occurring and potentially causing damage. In addition the map displays the essential facilities and the natural and beneficial function locations.


Louisville Metro Hazard Vulnerability - Harrods Creek Watershed
US HIGHWAY 42
HARRODS CREEK
KY-841
71
265
N
W
E
S
2 1 0 2 Miles
Essential Facilities
Natural and Beneficial Functions
Risk Score
Legend
Hazard Vulnerability / Risk Score
0
1 (Moderate)
2 (High)
3 (Severe)
Major Stream
Interstate
Major Road
Regulatory Floodplain
Open Space
Wetland
Hydric Soils
Overflow Abatement Plan Area
Sewer Draft Floodprone Area
Regulatory Floodplain
Emergency Operations Center
Emergency Telcommunications
Siren
Police Dept
Metro Fire Dept
County Fire Dept
Prison
EMS
Hospital
Immediate Care Center
Health Clinic
Nursing Home
Shelter
Daycare
School
College
Media Center
Military
Detention Basin
Flood Hotspot
Repetitive Loss Property
Severe Repetitive Loss Property
Historical Claim Property
Source: LOJIC
Copyright (c) 2010, LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT (MSD), LOUISVILLE WATER COMPANY (LWC), LOUISVILLE METRO GOVERNMENT, and JEFFERSON COUNTY PROPERTY VALUATION ADMINISTRATOR (PVA). All Rights Reserved.
LOJIC

3.7.3.9 Mill Creek Watershed

The 34 square mile Mill Creek Watershed is located in the western portion of Louisville Metro and contains 156.8 stream miles, most of it is in modified drainage channels. The Mill Creek Cutoff was constructed many years ago to re-route the upper watershed directly to the Ohio River. The Mill Creek Cutoff collects stormwater from the north end of Iroquois Park, Pleasure Ridge Park and Shively areas.



Due to the diversion of the upstream reaches of Mill Creek into the cut-off channel, this watershed is divided into two entirely separate sections: Upper Mill Creek and Lower Mill Creek. Major streams included in Upper Mill Creek include Big Run, Cane Run, and Mill Creek Cutoff. Major streams included in Lower Mill Creek include Mill Creek and Black Pond Creek.

The 19 square mile Upper Mill Creek's headwaters originate in the area of Manslick Road and I-264. From here, they flow in a westerly direction to the western side of Shively, where several tributaries including Cane Run, Boxwood Ditch, Lynnview Ditch, and Big Run join the flow. From this point, the flow direction is to the northwest, via the cutoff channel. The stream outlets into the Ohio River just south of Riverside Gardens. A flood pumping station is located in the Riverside Gardens area near the stream outlet. This flood pumping station is part of the flood levee system that protects Louisville Metro from Ohio River flooding.

The 15 square mile Lower Mill Creek's headwaters originate in the area of Lower Hunters Trace and Terry Road. From here, the flow is generally to the south, paralleling the Ohio River. Several tributaries, including Black Pond Creek and Valley Creek, join this flow in the Valley Downs area. The stream eventually outlets into the Ohio River west of Valley Village. A flood pumping station is located 0.75 miles upstream of the mouth of Lower Mill Creek. This flood pumping station is part of the flood levee system that protects Louisville Metro from Ohio River flooding.

Communities lying in the Upper Mill Creek section include Shively, Heatherfield, Hunters Trace, Parkwood, St. Denis, and Riverside Gardens. Notable landmarks include Louisville Gas & Electric's Mill Creek Power Station, Western High School, Doss High School, Shively Park, Dixie Manor, and a part of Iroquois Park. Sun Valley Park is located on Mill Creek near Lower River Road. This park provides preserved open space along Mill Creek.

Communities lying in the Lower Mill Creek section include Valley Village, Meadow Lawn, Valley Downs, parts of Valley Station and Pleasure Ridge Park, Sylvania, Greenwood, and Waverly Hills. Notable landmarks include Sun Valley Community Park, Valley High School, Waverly Park, and the Louisville and Jefferson County Riverport Authority.

Topography

The major portion of the Mill Creek Watershed is situated in the Flood Plain Topographic Region. The remaining portion, east of the Illinois Central Railroad, lies in the Knobs. A very flat, low-lying terrain predominates in the Flood Plain. Stream channels with low gradient slopes tend to parallel the Ohio River. Terraces of ten to twenty feet in height are common.

Steep-sided, round-topped hills dominate the terrain in the Knobs. Stream channels are deeply cut into these hills and commonly have high gradient slopes. Elevations range from about 382 feet, the pool stage of the Ohio River below the McAlpine Lock and Dam, to about 760 feet, at the top of the Iroquois Park hill.

Existing Structural Flood Controls

The Wheeler Basin is a regional basin located in the Mill Creek Watershed. The basin was constructed to relieve flooding from the combined sewer system.

Basic Watershed Flood Information

Depth of Water:

- Using the FIS Flood Profile data for Upper Mill Creek the mean average depth of flooding from the stream bed to the Regulatory Floodplain is 16.3 feet. This data was derived from 10 cross sections on Upper Mill Creek.
- Using the FIS Flood Profile data for Big Run Creek the mean average depth of flooding from the stream bed to the Regulatory Floodplain is 9.6 feet. This data was derived from 8 cross sections on Big Run Creek.
- Using the FIS Flood Profile data for Cane Run Ditch the mean average depth of flooding from the stream bed to the Regulatory Floodplain is 10.0 feet. This data was derived from 6 cross sections on Cane Run Ditch.
- Using the FIS Flood Profile data for Black Pond Creek the mean average depth of flooding from the stream bed to the Regulatory Floodplain is 11.7 feet. This data was derived from 9 cross sections on Black Pond Creek.

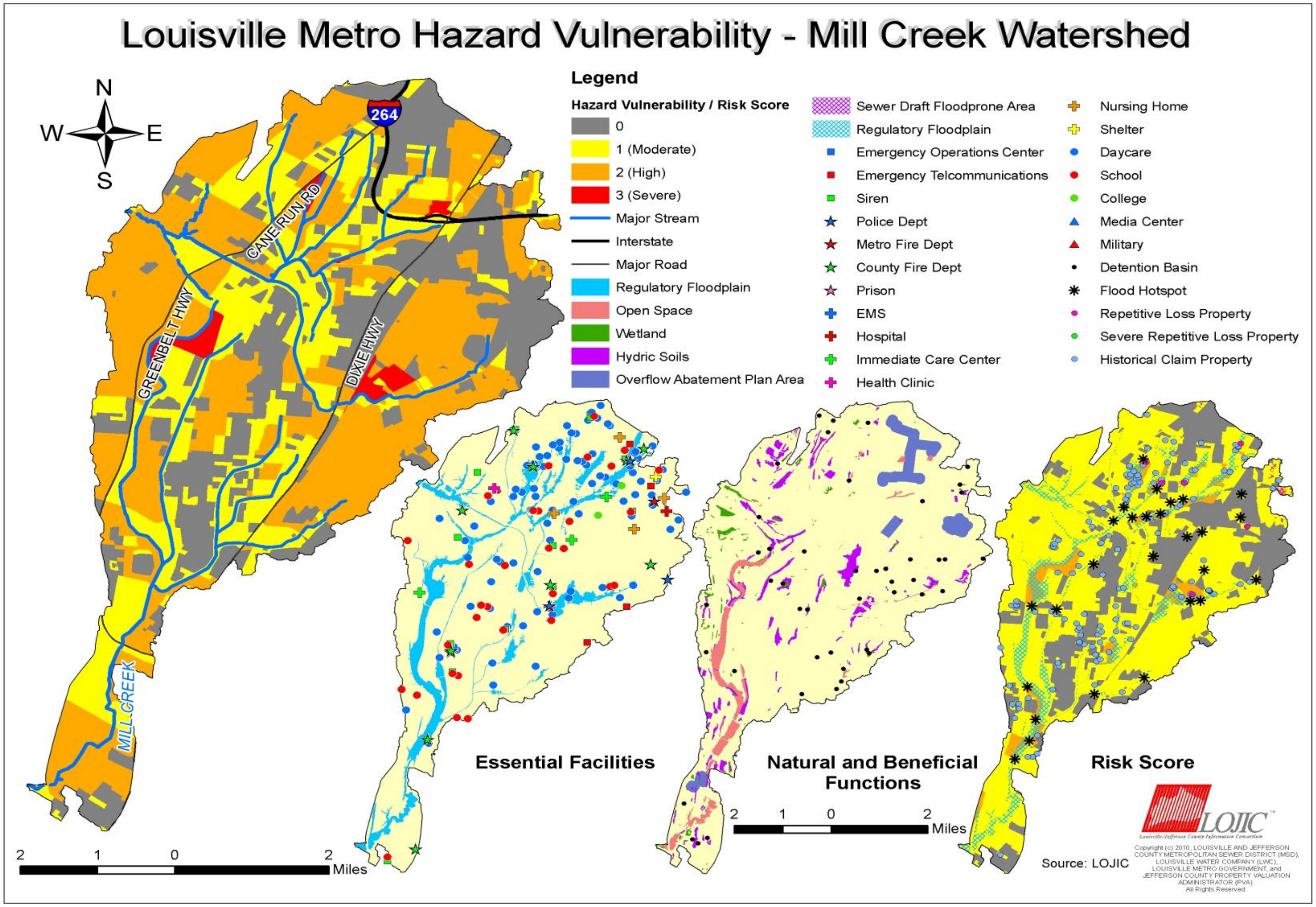
Velocities:

- Using the FIS Flood Profile data (Floodway) for Upper Mill Creek the mean average velocity is 4.8 feet per second. This data was derived from 10 cross sections on the Upper Mill Creek.
- Using the FIS Flood Profile data (Floodway) for Big Run Creek the mean average velocity is 5.1 feet per second. This data was derived from 8 cross sections on the Big Run Creek.
- Using the FIS Flood Profile data (Floodway) for Cane Run Ditch the mean average velocity is 1.7 feet per second. This data was derived from 6 cross sections on the Cane Run Ditch.

- Using the FIS Flood Profile data (Floodway) for Black Pond Creek the mean average velocity is 2.8 feet per second. This data was derived from 9 cross sections on the Black Pond Creek.

Note: The above information is a mean average for the flooding source. Specific locations will provide different outputs throughout the watershed. It should be noted that we can calculate a depth at any point within the floodplain by comparing the ground elevation from the digital terrain model to the flood elevation layer where data permits.

The following map depicts the Mill Creek Watershed Vulnerability Score map. This map details areas of high vulnerability based on several different factors such as: Regulatory Floodplain, "Draft" Combined Sewer Floodprone Area study, Repetitive Loss Properties, Severe Repetitive Loss Properties, Historical Claims data, and Flood Hotspot data. These variables provide a detailed Risk Score that displays areas at risk based on mapped floodplains and mapped occurrence hotspots. These two factors provide Louisville Metro with a comprehensive understanding of where flooding is occurring and potentially causing damage. In addition the map displays the essential facilities and the natural and beneficial function locations.


Louisville Metro Hazard Vulnerability - Mill Creek Watershed
Legend
Hazard Vulnerability / Risk Score
0
1 (Moderate)
2 (High)
3 (Severe)
Major Stream
Interstate
Major Road
Regulatory Floodplain
Open Space
Wetland
Hydric Soils
Overflow Abatement Plan Area
Sewer Draft Floodprone Area
Regulatory Floodplain
Emergency Operations Center
Emergency Telcommunications
Siren
Police Dept
Metro Fire Dept
County Fire Dept
Prison
EMS
Hospital
Immediate Care Center
Health Clinic
Nursing Home
Shelter
Daycare
School
College
Media Center
Military
Detention Basin
Flood Hotspot
Repetitive Loss Property
Severe Repetitive Loss Property
Historical Claim Property
N
W
E
S
264
CANE RUN RD
GREENBELT HWY
DIXIE HWY
MILL CREEK
2 1 0 2 Miles
Essential Facilities
Natural and Beneficial Functions
Risk Score
2 1 0 2 Miles
Source: LOJIC
LOJIC
Copyright (c) 2010, LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT (MSD), LOUISVILLE WATER COMPANY (LWC), LOUISVILLE METRO GOVERNMENT, and JEFFERSON COUNTY PROPERTY VALUATION ADMINISTRATOR (PVA). All Rights Reserved.

3.7.3.10 Pennsylvania Run Watershed

The seven square mile Pennsylvania Run Watershed is located in south central Louisville Metro and contains 33.4 stream miles, most of which are intermittent and ephemeral streams, with the exception of McNeeley Lake, a small recreational reservoir. Its headwaters originate in the Highview area, and the stream flows in a southerly direction, passing into Bullitt County, and eventually discharging into Cedar Creek. Pennsylvania Run is the only major stream in this watershed.

Pennsylvania Run originates from McNeely Lake and flows south. It merges with Cedar Creek in Louisville Metro, which eventually flows into Goose Creek downstream of Goose Creek at Bardstown Road.

Notable landmarks include McNeely Lake and McNeely Lake Park. McNeely Lake Park is located along Pennsylvania Run and provides preserved open space.

Topography

The entire Pennsylvania Run Watershed is situated in the Eastern Uplands Topographic Region. Broad, fairly steep-sided valleys and narrow ridge crests dominate the terrain. Streams have cut deeply into this terrain and flow through well-entrenched channels. Elevations vary from about 515 feet at the Jefferson County/Bullitt County line, to about 685 feet in the Highview area.

Existing Structural Flood Controls

No regional basins or major channel improvement projects are located in the Pennsylvania Run Watershed.

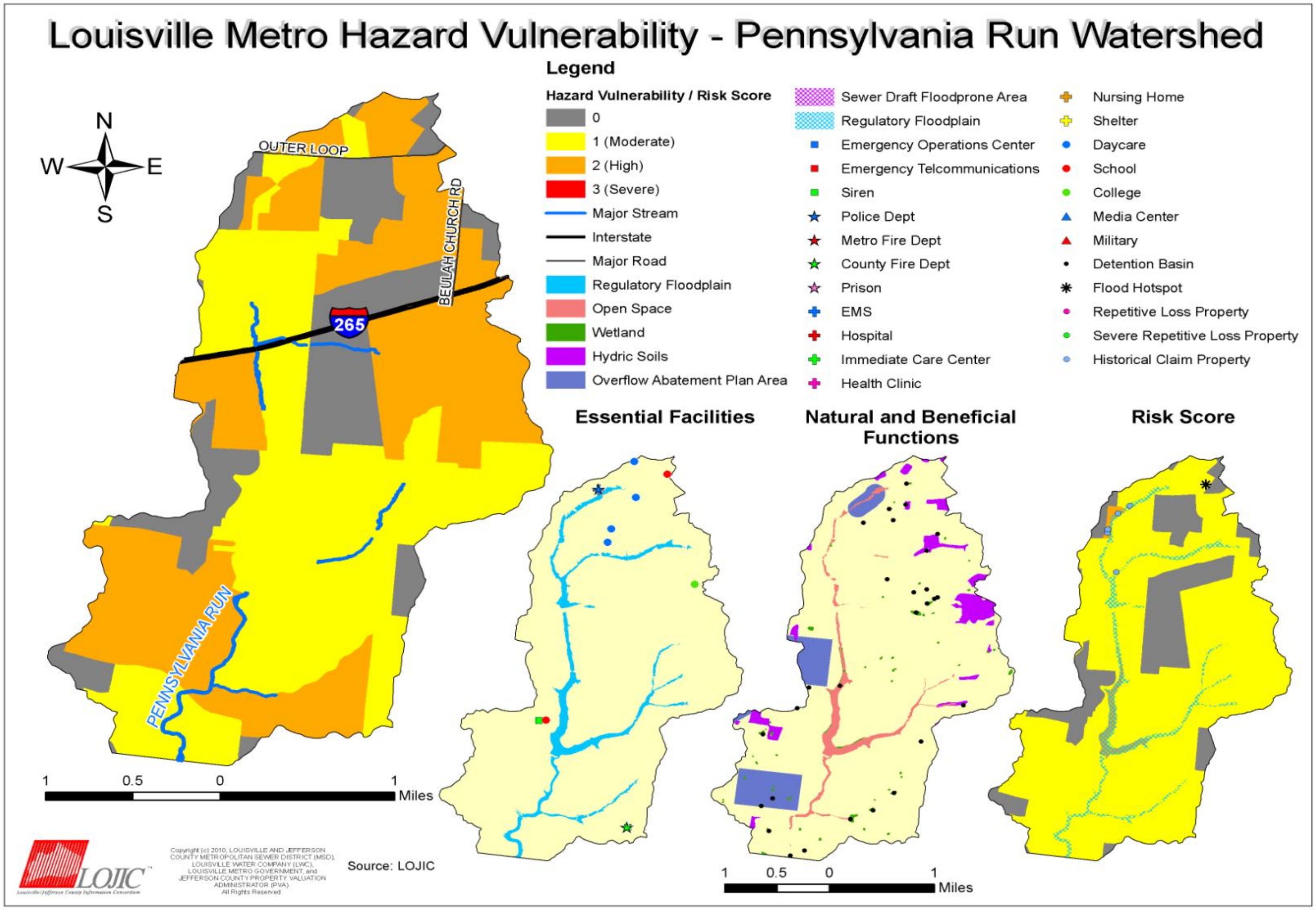
Basic Watershed Flood Information

Depth of Water: Using the FIS Flood Profile data for Pennsylvania Run the mean average depth of flooding from the stream bed to the Regulatory Floodplain is 6.3 feet. This data was derived from 52 cross sections on Pennsylvania Run.

Velocities: Using the FIS Flood Profile data (Floodway) for Pennsylvania Run the mean average velocity is 4.9 feet per second. This data was derived from 52 cross sections on the Pennsylvania Run.

Note: The above information is a mean average for the flooding source. Specific locations will provide different outputs throughout the watershed. It should be noted that we can calculate a depth at any point within the floodplain by comparing the ground elevation from the digital terrain model to the flood elevation layer where data permits.

The following map depicts the Pennsylvania Run Watershed Vulnerability Score map. This map details areas of high vulnerability based on several different factors such as: Regulatory Floodplain, Repetitive Loss Properties, Severe Repetitive Loss Properties, Historical Claims data, and Flood Hotspot data. These variables provide a detailed Risk Score that displays areas at risk based on mapped floodplains and mapped occurrence hotspots. These two factors provide Louisville Metro with a comprehensive understanding of where flooding is occurring and potentially causing damage. In addition the map displays the essential facilities and the natural and beneficial function locations.


Louisville Metro Hazard Vulnerability - Pennsylvania Run Watershed
Legend
Hazard Vulnerability / Risk Score
0
1 (Moderate)
2 (High)
3 (Severe)
Major Stream
Interstate
Major Road
Regulatory Floodplain
Open Space
Wetland
Hydric Soils
Overflow Abatement Plan Area
Sewer Draft Floodprone Area
Regulatory Floodplain
Emergency Operations Center
Emergency Telcommunications
Siren
Police Dept
Metro Fire Dept
County Fire Dept
Prison
EMS
Hospital
Immediate Care Center
Health Clinic
Nursing Home
Shelter
Daycare
School
College
Media Center
Military
Detention Basin
Flood Hotspot
Repetitive Loss Property
Severe Repetitive Loss Property
Historical Claim Property
N
W
E
S
OUTER LOOP
BEULAH CHURCH RD
265
PENNSYLVANIA RUN
Essential Facilities
Natural and Beneficial Functions
Risk Score
1 0.5 0 1 Miles
1 0.5 0 1 Miles
Copyright (c) 2010, LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT (MSD), LOUISVILLE WATER COMPANY (LWC), LOUISVILLE METRO GOVERNMENT, and JEFFERSON COUNTY PROPERTY VALUATION ADMINISTRATOR (PVA). All Rights Reserved
Source: LOJIC

3.7.3.11 Pond Creek Watershed

The 94 square mile Pond Creek Watershed is located in south central and southwest Louisville Metro and contains 649.6 stream miles in Louisville Metro. It is primarily drained by a series of natural and improved channels called Fern Creek, Northern Ditch, Southern Ditch, and Pond Creek. The headwaters of Fern Creek originate in the west side of Jeffersontown and flow southwest to Shepherdsville Road. At this point, the flow turns to the west and the improved channel is called Northern Ditch. This westerly flow continues into the vicinity of the Louisville and Nashville Railroad's Osborn Yard, where it turns southwest and finally outlets into Southern Ditch at the Outer Loop. The flow in Southern Ditch, an improved channel, originates in the Smyrna area and moves west, generally paralleling the Outer Loop. From this point, Southern Ditch flows to the west about three-quarters of a mile, then turns to the southwest and flows about one mile to Manslick Road. Downstream from Manslick Road, the natural channel is called Pond Creek. It flows in a generally southwesterly direction to its eventual outlet into the Salt River. Numerous tributaries enter these four main channels, including Fishpool Creek, Mud Creek, Wilson Creek, Bee Lick Creek, Greasy Ditch, Duck Spring Branch, Salt Block Creek, Slate Run, Bearcamp Run, Crane Run, Brier Run, and Weaver Run.

Once a backwater slough for the Ohio River floodplain with shallow lakes and swampy forests called "wetwoods," the hydrology of the central and lower reaches of this watershed have been completely modified over the past two centuries. Upstream subwatersheds in the Pond Creek watershed include Fern Creek, Fishpool Creek, Mud Creek and Wilson's Creek. Bee Lick, Manslick, Slop Ditch (now Wetwoods Creek), Greasy Ditch, Blue Spring Ditch, Duck Spring Branch and other channelized drainage ditches also feed into the central drainage canals called Northern Ditch and Southern Ditch.

Brier Creek along the southern border of the county is in a rural valley in the Knobs, below Jefferson Forest. Brier Creek originates in Metz Gap and Jefferson Hill close to the Jefferson County Memorial Forest and flows west before merging into Pond Creek. Brier Creek is described as an independent watershed from Pond Creek.

Communities situated in this watershed include parts of Jeffersontown, Fern Creek, Highview, Newburg, Smyrna, Okolona, Lynnview, Auburndale, Fairdale, Prairie Village, Medora, Orell, and part of Valley Station. Notable landmarks include the Louisville International Airport, General Electric's Appliance Park, Ford Louisville Assembly Plant, Jefferson Mall, part of Iroquois Park, Komosdale Cement Plant, and much of the Jefferson County Memorial Forest. Three USGS gauges are located in the Pond Creek Watershed, including two on Pond Creek and one on Northern Ditch. Roberson Run Park is located along Roberson Run, a tributary of Pond Creek, and provides preserved open space along that tributary.

Topography

The Pond Creek Watershed is unique, in that it encompasses parts of all four of Louisville Metro's Topographic Regions. Fern Creek is in the Eastern Uplands. Northern and Southern Ditch are in the Central Basin. Pond Creek has eroded a trench through the knobs and drains a portion of the Flood Plain.

In the Eastern Uplands Topographic Region, broad steep-sided valleys and gently rolling plateaus dominate the terrain. Major streams have cut deeply into this terrain and they flow through well-entrenched channels.

In the Central Basin Topographic Region, an extremely flat, low-lying terrain predominates. This was formerly a swampy area. The major streams have been greatly improved and flow in well entrenched, though very low gradient slope, channels.

In the Knobs Topographic Region, steep-sided, round-topped hills dominate the terrain. Stream channels are deeply cut into these hills and commonly have high gradient slopes.

In the Flood Plain Topographic Region, a very flat, low-lying terrain predominates. Stream channels of low gradient slopes tend to parallel the Ohio River, and terraces of ten to twenty feet in height are common.

Elevations range from about 382, the pool stage of the Ohio River below the McAlpine Lock and Dam, to in excess of 900 feet, along the county's southern boundary.

Existing Structural Flood Controls

The first regional basin built by MSD was the Roberson Run Basin. It was built in the early 1990s and is relatively small. Although the impacts on flooding are minimal by today's standards, the basin is a multiuse facility with the incorporation of walking paths around the basin that link adjoining residential areas.

In 1998, MSD, Jefferson County Government, and the U.S. Army Corps of Engineers began the construction phase of the Pond Creek Flood Prevention Project. The final phase of this project is currently underway.

The project will utilize large basins for flood storage and channel improvements to remove an estimated 2,000 buildings from the danger of most floods. In addition, the project will incorporate Greenways principles that will provide pedestrian access to Pond Creek. Walking and biking paths will help connect neighborhoods and introduce area residents to ever improving water quality along Pond Creek. A description of each phase of the project is listed below.

- Phase I: The Okolona Wetlands Restoration Site is an environmental restoration of 15 acres of wetlands located in a former sludge lagoon at the former Okolona Wastewater Treatment Plant. The restoration process included draining the area of sludge and replanting native vegetation. The plans for this restoration phase have been completed.

- Phase II: The Vulcan Detention Basin included constructing a dam on Fishpool Creek, installing a low-flow pipe, and constructing an overflow structure into the basin which was a limestone quarry. The basin was designed to fill during a 24-hour storm event and drain over a period of approximately eight days. This basin became operational in September 1999. The capacity of the detention basin is 450 acre-feet. A diversion dam was constructed across the creek and an 18'' pipe was placed through the dam to maintain base flows.
- Phase III: The Melco Detention Basin behind the Ford Motor Plant was completed in 2001. It expanded an existing 15-acre borrow pit to 80 acres, which increased the storage capacity to 1,500 acre-feet.
- Phase IV: This phase included channel modifications to Northern Ditch between Preston Highway and the Melco Basin inlet. It also included widening one bank of Northern Ditch for a distance of almost 1.5 miles, replacing culverts, and installing riffle structures and pools in the stream to improve aquatic habitat.
- Phase V: Channel modifications to Pond Creek and the placement of a multipurpose recreation trail alongside the creek are currently under construction. This phase includes widening one bank of Pond Creek for a distance of 2.4 miles, replacing culverts, and installing riffle structures and pools in the stream to improve aquatic habitat.

In addition to the Army Corps of Engineers project, MSD has also worked with a private company to create a floodplain and runoff compensation bank located in the Pond Creek Watershed. This compensation bank is funded though private development. It consists of three basins. Ponds 1 and 2 have been constructed. Pond 1 is located near I-65 and the Outer Loop and is 80 ac-ft. Pond 2 is located near Wilson Creek and the Gene Snyder Freeway and is 26.5 ac-ft. Pond 3 is currently under construction. This pond is located at National Turnpike and Southern Ditch and will be 234 ac-ft

Basic Watershed Flood Information

Depth of Water:

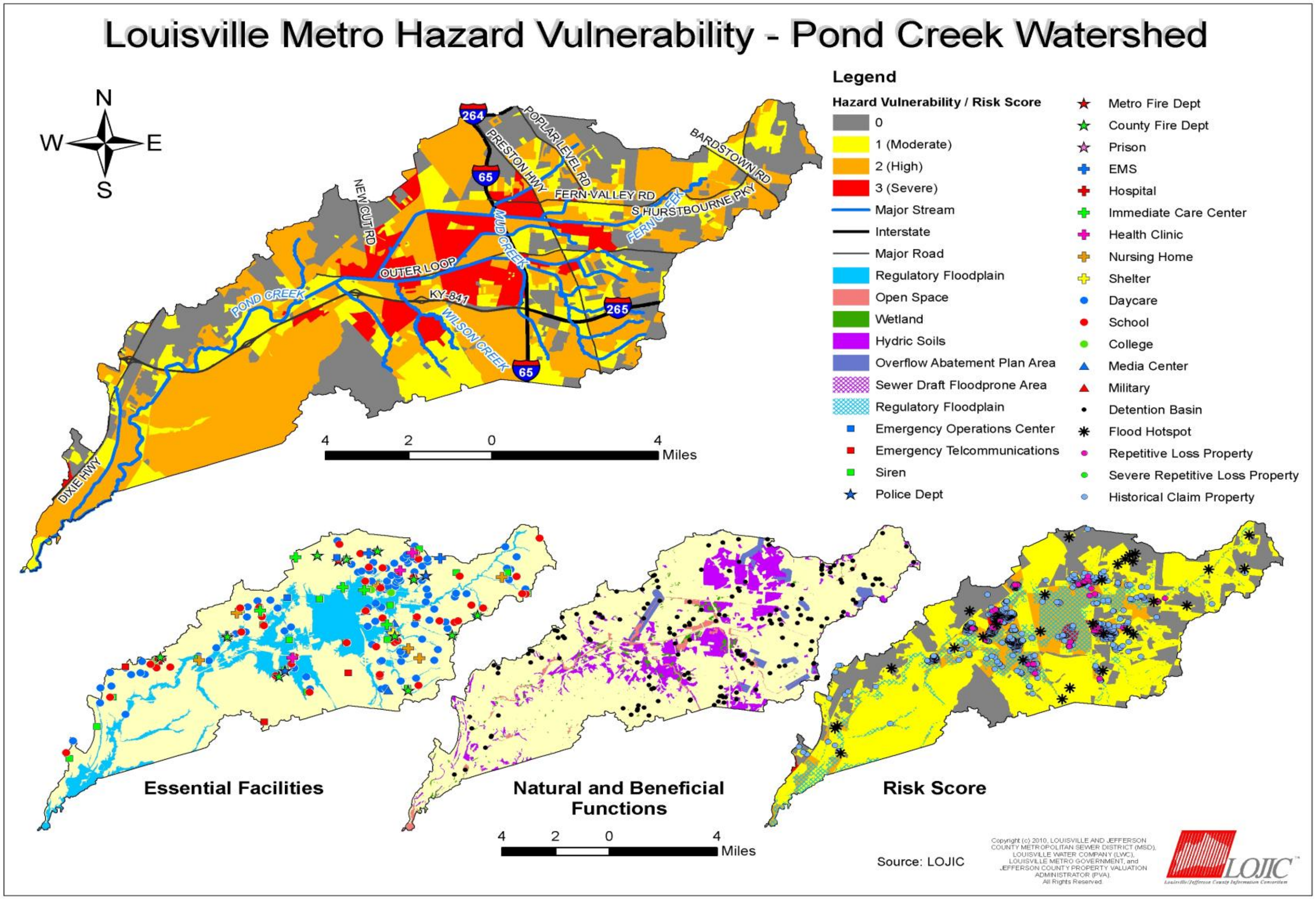
- Using the FIS Flood Profile data for Pond Creek the mean average depth of flooding from the stream bed to the Regulatory Floodplain is 16.3 feet. This data was derived from 10 cross sections on Pond Creek.
- Using the FIS Flood Profile data for Northern Ditch the mean average depth of flooding from the stream bed to the Regulatory Floodplain is 16.0 feet. This data was derived from 13 cross sections on Northern Ditch.
- Using the FIS Flood Profile data for Southern Ditch the mean average depth of flooding from the stream bed to the Regulatory Floodplain is 9.0 feet. This data was derived from 42 cross sections on Southern Ditch.
- Using the FIS Flood Profile data for Fern Creek the mean average depth of flooding from the stream bed to the Regulatory Floodplain is 12.8 feet. This data was derived from 5 cross sections on Fern Creek.

Velocities:

- Using the FIS Flood Profile data (Floodway) for Pond Creek the mean average velocity is 4.8 feet per second. This data was derived from 10 cross sections on the Pond Creek.
- Using the FIS Flood Profile data (Floodway) for Northern Ditch the mean average velocity is 3.7 feet per second. This data was derived from 13 cross sections on the Northern Ditch.
- Using the FIS Flood Profile data (Floodway) for Southern Ditch the mean average velocity is 5.0 feet per second. This data was derived from 42 cross sections on the Southern Ditch.
- Using the FIS Flood Profile data (Floodway) for Fern Creek the mean average velocity is 4.3 feet per second. This data was derived from 5 cross sections on the Fern Creek.

Note: The above information is a mean average for the flooding source. Specific locations will provide different outputs throughout the watershed. It should be noted that we can calculate a depth at any point within the floodplain by comparing the ground elevation from the digital terrain model to the flood elevation layer where data permits.

The following map depicts the Pond Creek Watershed Vulnerability Score map. This map details areas of high vulnerability based on several different factors such as: Regulatory Floodplain, Repetitive Loss Properties, Severe Repetitive Loss Properties, Historical Claims data, and Flood Hotspot data. These variables provide a detailed Risk Score that displays areas at risk based on mapped floodplains and mapped occurrence hotspots. These two factors provide Louisville Metro with a comprehensive understanding of where flooding is occurring and potentially causing damage. In addition the following maps display the essential facilities and the natural and beneficiary function locations.


Louisville Metro Hazard Vulnerability - Pond Creek Watershed
Legend
Hazard Vulnerability / Risk Score
0
1 (Moderate)
2 (High)
3 (Severe)
Major Stream
Interstate
Major Road
Regulatory Floodplain
Open Space
Wetland
Hydric Soils
Overflow Abatement Plan Area
Sewer Draft Floodprone Area
Regulatory Floodplain
Emergency Operations Center
Emergency Telcommunications
Siren
Police Dept
Metro Fire Dept
County Fire Dept
Prison
EMS
Hospital
Immediate Care Center
Health Clinic
Nursing Home
Shelter
Daycare
School
College
Media Center
Military
Detention Basin
Flood Hotspot
Repetitive Loss Property
Severe Repetitive Loss Property
Historical Claim Property
N
W
E
S
264
65
265
POPLAR LEVEL RD
PRESTON HWY
BARDSTOWN RD
FERN VALLEY RD
S HURSTBOURNE PKY
FERN CREEK
NEW CUT RD
MUD CREEK
OUTER LOOP
KY-841
POND CREEK
WILSON CREEK
DIXIE HWY
4 2 0 4
Miles
Essential Facilities
Natural and Beneficial Functions
Risk Score
Source: LOJIC
Copyright (c) 2010, LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT (MSD), LOUISVILLE WATER COMPANY (LWC), LOUISVILLE METRO GOVERNMENT, and JEFFERSON COUNTY PROPERTY VALUATION ADMINISTRATOR (PVA). All Rights Reserved.
LOJIC

3.7.3.12 Basic Watershed Flood Information

The following table combines all of the watersheds "*Basic Watershed Flood Information".*

Watershed	Flooding Source	Avg. Depth of Water	Avg. Velocities
OHIO RIVER/CITY	Ohio River	80	4.9
MIDDLE FORK BEARGRASS CREEK	Middle Fork Beargrass Creek	13.2	4.9
	Weicher Creek	5.4	3.8
MUDDY FORK BEARGRASS CREEK	No data	No Data	No data
SOUTH FORK BEARGRASS CREEK	South Fork Beargrass Creek	14.6	5
	Buechel Branch	9.9	3.4
CEDAR CREEK	Cedar Creek	23.5	No data
FLOYDS FORK	Floyds Fork	22.3	4.9
GOOSE CREEK	Goose Creek	4.9	4.7
HARRODS CREEK	Harrods Creek	41	7.3
	South Fork Hite Creek	8.2	4
MILL CREEK	Upper Mill Creek	16.3	4.8
	Big Run Creek	9.6	5.1
	Cane Run Ditch	10	1.7
	Black Pond Creek	11.7	2.8
PENNSYLVANIA RUN	Pennsylvania Run	6.3	4.9
POND CREEK	Pond Creek	16.3	4.8
	Northern Ditch	16	3.7
	Southern Ditch	9	5
	Fern Creek	12.8	4.3

Note: The Average Depth of Water was calculated from the stream bed to the Regulatory Floodplain based on the 2006 Louisville and Jefferson County Kentucky FIS. The Average Velocities were calculated from the same report.

3.8 Hail

Description: Hail is precipitation in the form of spherical or irregular pellets of ice larger than 5 millimeters (0.2 inches) in diameter (*American Heritage Dictionary*).

In the U. S.

Hailstones can fall at speeds of up to 120 mph. Hail is responsible for nearly $1 billion in damage to crops and property each year in the U.S.

Hail is a somewhat frequent occurrence associated with severe thunderstorms. Hailstones grow as ice pellets are lifted by updrafts, and collect super-cooled water droplets. As the pellets grow, hailstones become heavier and begin to fall. Sometimes, hailstones are caught by successively stronger updrafts and are re-circulated through the cloud growing larger each time the cycle is repeated. Eventually, the updrafts can no longer support the weight of the hailstones. As hailstones fall to the ground, they produce a hail-streak (i.e. area where hail falls) that may be more than a mile wide and a few miles long.

Hail Types

Hail is a unique and common hazard capable of producing extensive damage from the impact of these falling objects. Hailstorms occur more frequently during the late spring and early summer months. Most thunderstorms do not produce hail, and ones that do normally produce only small hailstones not more than one-half inch in diameter.

Hail Conversion Chart	
Diameter of Hailstones (inches)	**Description**
0.50	Marble
0.70	Dime
0.75	Penny
0.88	Nickel
1.00	Quarter
1.25	Half Dollar
1.50	Walnut
1.75	Golf Ball
2.00	Hen Egg
2.50	Tennis Ball
2.75	Baseball
3.00	Tea Cup
4.00	Grapefruit
4.50	Softball

3.8.1 Hail Profile

SUMMARY OF HAILSTORM RISK FACTORS

Period of occurrence:	Year-round
Number of Events to-date: 1961-2010	46
Probability of event(s):	0.94
Warning time:	Minutes to hours
Potential Impact(s):	Large hailstorms can include minimal to severe property and crop damage and destruction.
Past Damages	$27,884,579

Historical Impact: The effects of large hailstorms can include minimal to severe property and crop damage and destruction. Most thunderstorms do not produce hail, and ones that do normally produce only small hailstones not more than one-half inch in diameter.

Potential Impacts of Hail: Large hailstorms can include minimal to severe property and crop damage and destruction. The combination of gravity and a downward wind known as a downburst (a common occurrence during severe thunderstorms) can propel a hailstone at speeds upwards of 90 mph. At such excessive speeds, large hailstones have been known to penetrate straight through roof coverings and the deck to which they are attached. Although the majority of hailstorms are not quite so severe, even moderate hailstorms can damage buildings, automobiles, crops, and other personal property.

The following event detail information is typical of damage and injury caused by hailstorms within the Louisville Metro planning area over the past five years.

> **Louisville NWS Hail Reports**
>
> **Largest:** 2.75" hail (baseball size) on May 3, 1996 at Jeffersontown, Fern Creek, Camp Taylor, and Highview (accumulated 8" deep).

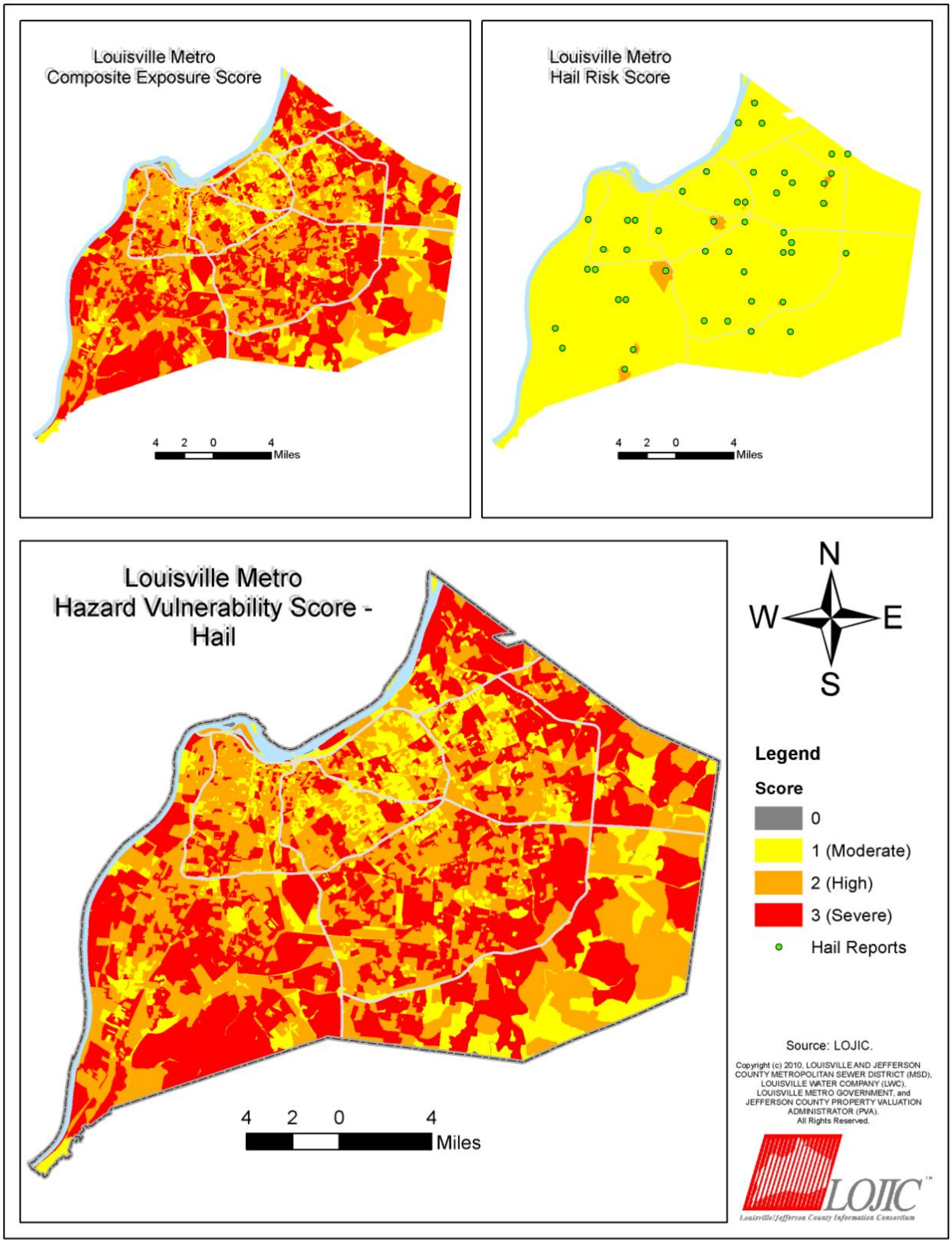
- **19 May 2005, 2 events:**
    - A lightning strike caused a house fire on Waters Edge Drive. There were also widespread reports of large hail, and a few more reports of non-severe hail in other locations. Flooding of low-lying areas, and streams flowing out of banks, also resulted from the thunderstorms. $10K
    - A lightning strike caused a house fire on Pepperdine Court. There were also widespread reports of large hail, and a few more reports of non-severe hail in other locations. Flooding of low-lying areas, and streams flowing out of banks, also resulted from the thunderstorms. $10K

- **2 April 2006, 1 event**
    - Quarter size hail broke windows along Bardstown Road. $2K
- **18 October 2007, 1 event**
    - Hail 1.25 inch in diameter fell in the Crescent Hill area with a storm that later produced a brief EF0 tornado farther east. A cold front with strong upper level support collided with a very moist air mass over the lower Ohio Valley. The result was a widespread outbreak of severe thunderstorms, and six confirmed tornadoes. The storms produced property damage, downed trees and power lines, and large hail. $10K

3.8.1.1 Assessing Vulnerability Overview: Hail

Hail Vulnerability Score = Exposure Score X Risk Score

Assessing vulnerability by census block was determined through creating the Hail Risk Score using the Hail Occurrence Rank. The Hail Occurrence Rank was calculated using GIS point data provided by the NOAA Storm Prediction Center's SVRGIS datasets. These datasets geo-locate hail occurrences throughout the United States. The GIS staff took the national dataset and clipped it to Louisville Metro using a spatial analysis clip tool within GIS. The Hail Occurrence Rank was then calculated by counting the number of occurrences within each census block and then ranked 0 to 3 (0 = No data, 1 = Moderate, 2 = High, and 3 = Severe). This model displayed the areas of high probability based on past events occurring in a particular location. The Hail Vulnerability Score was calculated for each census block by multiplying the census block's Exposure Score by its Hail Risk Score.


Louisville Metro
Composite Exposure Score
4 2 0 4
Miles
Louisville Metro
Hail Risk Score
4 2 0 4
Miles
Louisville Metro
Hazard Vulnerability Score -
Hail
4 2 0 4
Miles
N
W
E
S
Legend
Score
0
1 (Moderate)
2 (High)
3 (Severe)
Hail Reports
Source: LOJIC.
Copyright (c) 2010, LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT (MSD), LOUISVILLE WATER COMPANY (LWC), LOUISVILLE METRO GOVERNMENT, and JEFFERSON COUNTY PROPERTY VALUATION ADMINISTRATOR (PVA).
All Rights Reserved.
LOJIC
Louisville/Jefferson County Information Consortium

3.8.1.2 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: Hail

In order to determine structures that are vulnerable and estimated to be damaged during a Hail event the Project Staff used the Hazard Boundary Overlay methodology. The Hazard Boundary used as the overlay was the Severe (3) census blocks. The Severe (3) census blocks identify areas of high probability for a Hail event, thus were used to showcase areas of severe risk in this model.

The following table describes the total number of structures identified within the hazard boundary and the replacement cost of those structures. This model estimates complete damage of each structure located within the Hazard Boundary.

HAIL	STRUCTURES
COMMERCIAL	7,327
INDUSTRIAL	1,571
RESIDENTIAL	57,740
OTHER	5,062
TOTAL BUILDINGS	**71,700**
ESTIMATED LOSS	**$13,987,315,397**

3.9 Hazardous Materials (HAZ/MAT)

Description: Hazardous materials or HAZ/MAT, are solids, liquids, or gases that can harm people, other living organisms, property, or the environment and they are often subject to chemical regulations. "HazMat teams" are personnel specially trained to handle dangerous goods.

Hazardous materials are often indicated by diamond-shaped signage. The colors of each diamond in a way has reference to its hazard i.e.: Flammable = red, Explosive = orange, because mixing red (flammable) with yellow (oxidizing agent) creates orange. Non Flammable Non Toxic Gas = green.

Haz-mat Sources: Hazardous materials include materials that are radioactive, flammable, explosive, corrosive, oxidizing, asphyxiating, biohazardous, toxic, pathogenic, or allergenic. Also included are physical conditions such as compressed gases and liquids or hot materials, including all goods containing such materials or chemicals, or may have other characteristics that render them hazardous in specific circumstances.

Chemical manufacturers are one source of hazardous materials, but there are many others, including service stations, hospitals, and hazardous materials waste sites. Varying quantities of hazardous materials are manufactured, used, or stored at an estimated 4.5 million facilities in the United States--from major industrial plants to local dry cleaning establishments or gardening supply stores.

Haz-Mat impacts

Hazardous materials in various forms can cause death, serious injury, long-lasting health effects, and damage to buildings, homes, and other property. Many products containing hazardous chemicals are routinely used and stored in homes. These products are also shipped daily on the nation's highways, railroads, waterways, and pipelines.

Hazardous materials planning occurs per the requirements of Title III of the Super Fund Amendments and Reauthorization Act (SARA) of 1986, Comprehensive Environmental Response Compensation and Liability Act (CERCLA) of 1980 and EPA Clean Air Act of 1990, RMP, as provided for in Section 112(r).

Mitigating the risks associated with hazardous materials may require the application of safety precautions during their transport, use, storage and disposal. Laws and regulations on the use and handling of hazardous materials may differ depending on the activity and status of the material. For example, one set of requirements may apply to their use in the workplace while a different set of requirements may apply to spill response, sale for consumer use, or transportation.

3.9.1 Hazardous Materials (HAZ/MAT) Profile

SUMMARY OF HAZ/MAT RISK FACTORS

Period of occurrence:	Anytime
Number of Events to-date 1986-2010:	999
Probability of event(s):	41.63
Warning time:	Minutes to hours
Potential Impact(s):	Impacts human life, health, and public safety. Mass evacuations and potential surge medical events.
Past Damages:	No data

Historical Impact: Industrial community hazardous materials can be found almost anywhere and releases of the materials into the environment can be deadly events. These releases can occur at almost any time, but in conjunction with another natural disaster such as a flood or earthquake the damages can multiply exponentially.

Louisville Haz-Mat History:

In the late 1970s and early 1980s, MSD was at the center of several serious hazardous material incidents that gained regional and national media attention. In 1985, the governments of both the City of Louisville and Jefferson County adopted an Ordinance requiring the submittal of a Hazardous Materials Use and Spill Prevention Control (HMPC) Plan by any business that manufactures, uses or stores hazardous materials in excess of designated quantities. The HMPC plan must state how a business will respond to spills or discharges of these materials. The Ordinance also directs the MSD to administer and enforce the program.

The current Louisville Metro Hazardous Materials Ordinance was approved on July 2, 2007 as Ordinance No. 121, Series 2007 which amended and re-enacted Chapter 95 of the Louisville Metro Code of Ordinances. The purpose of the ordinance is for the protection of public health and safety through the prevention and control of hazardous materials incidents and releases and to require the timely reporting of releases. The MSD was designated as the lead agency in administering the ordinance.

The following event detail information summarizes Louisville's 1977 haz-mat event.

- "*Hexa" and "Octa Event*; On March 17, 1977, employees at the Morris Forman plant noticed a strong, chemical odor that made them sick. It was the beginning of an environmental incident that would set legal precedent in the United States. It took more than a week to identify the highly toxic chemicals used in pesticides as a mixture of hexachloropentadiene and octachlorocyclopentene, quickly abbreviated to "hexa" and "octa." The contaminated treatment plant was shut down on March 29th, discharging 100 million gallons of untreated wastewater into the river each day.

The U.S. Army sent teams wearing protective gear into the sewers to find the source of the chemicals and the FBI joined the investigation. June 7th, a federal grand jury charged Donald E. Distler, president of Kentucky Liquid Recycling, and two of his employees with dumping toxic chemicals into the sewers. The chemicals were wastes that had been sent to Distler's company for disposal and Distler's company dumped them down a manhole in western Louisville.

The treatment plant was shut down for nearly three months while the contaminated material was removed — three months of discharging all the raw sewage into the river. It took another two years to remove the contaminated material from the sewer lines — years during which the raw sewage from these lines was shunted around the plant and into the river.

In September, 1979, the month the cleanup ended, Distler was found guilty — the first time an individual was convicted in a trial of federal criminal charges of polluting a waterway. He was sentenced to two years in prison and fined $50,000. After appealing all the way to the U.S. Supreme Court, he was sent to prison in early 1982.

In January, 1983, the companies that had originated the waste — Velsicol Chemical Corp. of Chicago and Chem-Dyne Corp. of Hamilton, Ohio — agreed to pay MSD $1.9 million for the medical costs of employees and the costs of cleaning up the sewers and the treatment plant.

- *The Sewer Explosions* - Friday, February 13, 1981, two women going to work at a hospital drove under the railroad overpass on Hill Street near 12th Street when there was a gigantic blast, and their car was hurled into the air and onto its side. At the same time, a police helicopter was heading toward the downtown area when the officers saw an unforgettable sight: a series of explosions, "like a bombing run," erupting along the streets of Old Louisville and through the University of Louisville campus.

More than two miles of Louisville streets were pockmarked with craters where manholes had been and several blocks of Hill Street had fallen into the collapsed, 12-foot-diameter sewer line. Miraculously, no one was hurt seriously, but homes and businesses were extensively damaged and some families had to be evacuated. Louisville was in the headlines and on broadcast news throughout the country for several days.

The sewer explosions started here, at a railroad underpass on Hill Street.

Courier-Journal and Louisville Times Photo by Larry Spitzer

The cause of the explosion was traced to the Ralston-Purina soybean processing plant southeast of the university campus, where thousands of gallons of a highly flammable solvent, hexane, had spilled into the sewer lines. The fumes from the hexane created an explosive mixture, which lay in wait in the larger sewer lines. As the women drove under the overpass, a spark from their car apparently ignited the gases.

Several blocks of Hill Street soon became an open trench, as crews cleared away the debris and prepared to replace the sewer line. The trench remained open throughout the summer while work continued. It took 20 months to repair the sewer lines, and another several months to finish the work on the streets.

Ralston-Purina pleaded guilty of four counts of violating federal environmental laws, and paid a fine of $62,500. In February, 1984, the company agreed to pay MSD more than $18 million in damages. Many millions more were paid to other government agencies and private individuals who suffered damage.

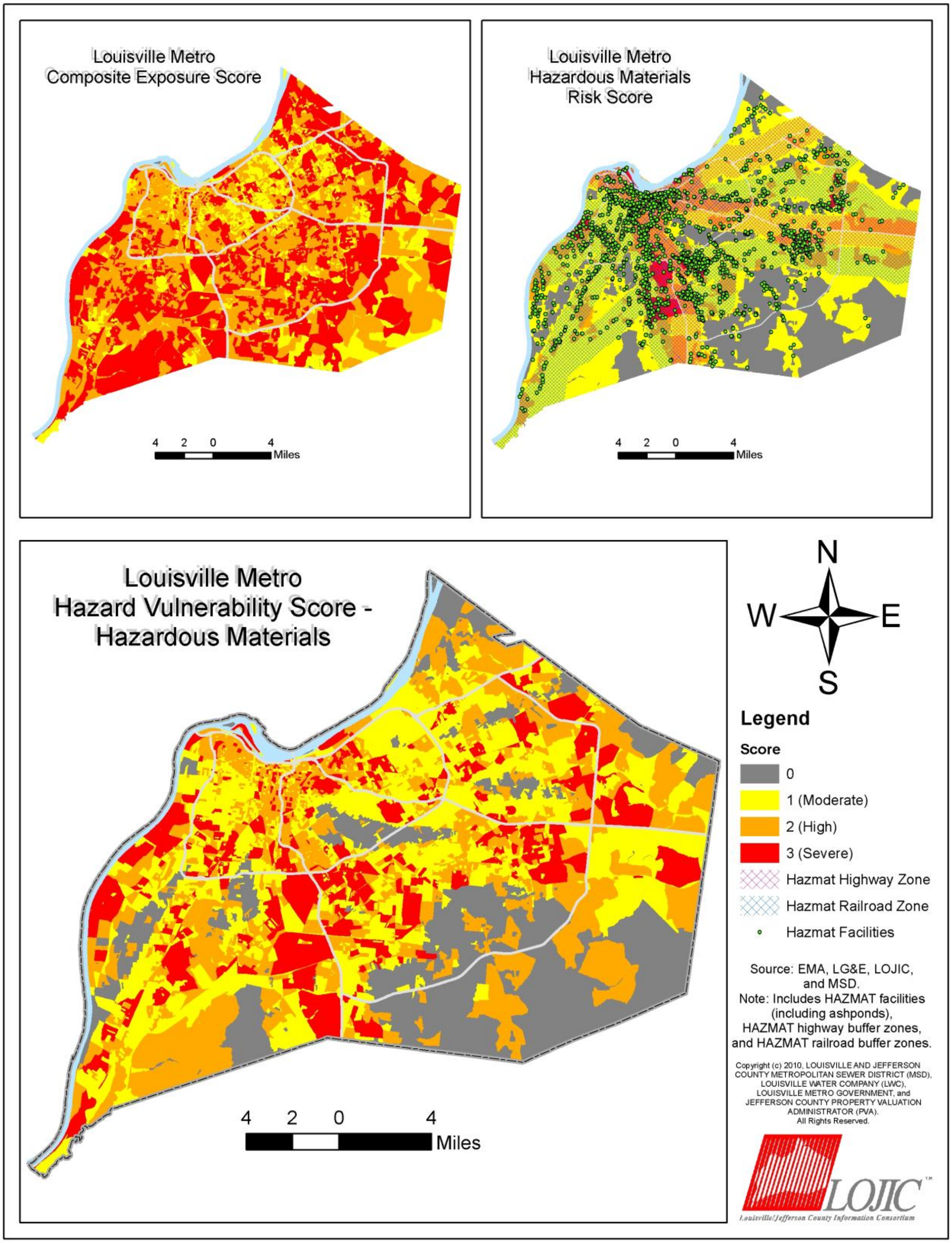
3.9.1.1 Assessing Vulnerability Overview: HAZ/MAT

HAZ/MAT Vulnerability Score = Exposure Score X Risk Score

Assessing vulnerability by census block was determined through creating the HAZ/MAT Risk Score adding the Occurrence Rank and Area Affected Rank. The Occurrence Rank was determined by counting the number of HAZ/MAT facilities located within each census block. . The Occurrence Rank provided an understanding of where high concentrations of Hazardous Materials are located within the community, thus producing areas of risk. The census blocks were then ranked 0 to 3 (0 = No data, 1 = Moderate, 2 = High, and 3 = Severe). The Area Affected Rank was determined using a 1 mile buffer around the communities Highways and Railways as the Hazard Boundary. The GIS staff identified transportation routes that allowed the transport of HAZ/MAT. The 1 mile buffer was chosen due to the fact that typically during a HAZ/MAT incident the response is to evacuate a 1 mile radius from the event.

The Area Affected Rank was calculated by taking the percent of the census block affected by the HAZ/MAT 1 mile highway and railway buffer zones. The percentage of area affected by the 1 mile buffer area was then calculated and ranked 0 to 3 (0 = No data, 1 = Moderate, 2 = High, and 3 = Severe). Next, the HAZ/MAT Occurrence Rank and Area Affected Rank scores were added together to produce the HAZ/MAT Risk Score.

The HAZ/MAT Vulnerability Score was calculated for each census block by multiplying the census block's Exposure Score by its HAZ/MAT Failure Risk Score.


Louisville Metro
Composite Exposure Score
4 2 0 4
Miles
Louisville Metro
Hazardous Materials
Risk Score
4 2 0 4
Miles
Louisville Metro
Hazard Vulnerability Score -
Hazardous Materials
4 2 0 4
Miles
N
W
E
S
Legend
Score
0
1 (Moderate)
2 (High)
3 (Severe)
Hazmat Highway Zone
Hazmat Railroad Zone
Hazmat Facilities
Source: EMA, LG&E, LOJIC, and MSD.
Note: Includes HAZMAT facilities (including ashponds), HAZMAT highway buffer zones, and HAZMAT railroad buffer zones.
Copyright (c) 2010, LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT (MSD), LOUISVILLE WATER COMPANY (LWC), LOUISVILLE METRO GOVERNMENT, and JEFFERSON COUNTY PROPERTY VALUATION ADMINISTRATOR (PVA). All Rights Reserved.
LOJIC
Louisville/Jefferson County Information Consortium

3.9.1.2 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: HAZ/MAT

In order to determine structures that are vulnerable and estimated to be damaged during a HAZ/MAT event the Project Staff used the Hazard Boundary Overlay methodology. The Hazard Boundary used as the overlay was the HAZ/MAT 1 mile buffer area. This HAZ/MAT 1 mile buffer area displays areas that are potentially at risk based on their proximity to the highways and railways that allow HAZ/MAT transport.

The following table describes the total number of structures identified within the hazard boundary and the replacement cost of those structures. This model estimates complete damage of each structure located within the Hazard Boundary.

HAZ/MAT	STRUCTURES
COMMERCIAL	21,190
INDUSTRIAL	3,566
RESIDENTIAL	177,776
OTHER	9,880
TOTAL BUILDINGS	**212,412**
ESTIMATED LOSS	**$ 31,049,546,041**

3.10 Karst/Sinkhole

Description: Karst is an area of irregular limestone in which erosion has produced fissures, sinkholes, underground streams, and caverns. A sinkhole is a natural depression in a land surface communicating with a subterranean passage, generally occurring in limestone regions and formed by solution or by collapse of a cavern roof (*American Heritage Dictionary*).

In the U. S.

Sinkhole collapses are commonly repaired by dumping any available material into the hole. This technique usually diverts water to other locations and lessons the likelihood of collapse.

Karst refers to a type of topography formed in limestone, dolomite, or gypsum by dissolution of these rocks by rain and underground water. It is characterized by closed depressions or sinkholes and underground drainage. During the formation of Karst terrain, water percolating underground enlarges subsurface flow paths by dissolving the rock. As some subsurface flow paths are enlarged over time, water movement in the aquifer changes character from one where ground water flow was initially through small, scattered openings in the rock, to one where most flow is concentrated in a few, well-developed conduits. As the flow paths continue to enlarge, caves may be formed and the ground water table may drop below the level of surface streams. Surface streams may then begin to lose water to the subsurface. As more of the surface water is diverted underground, surface streams and stream valleys become a less conspicuous feature of the land surface and are replaced by closed basins. Funnels or circular depressions called sinkholes often develop at some places in the low points of these closed basins.

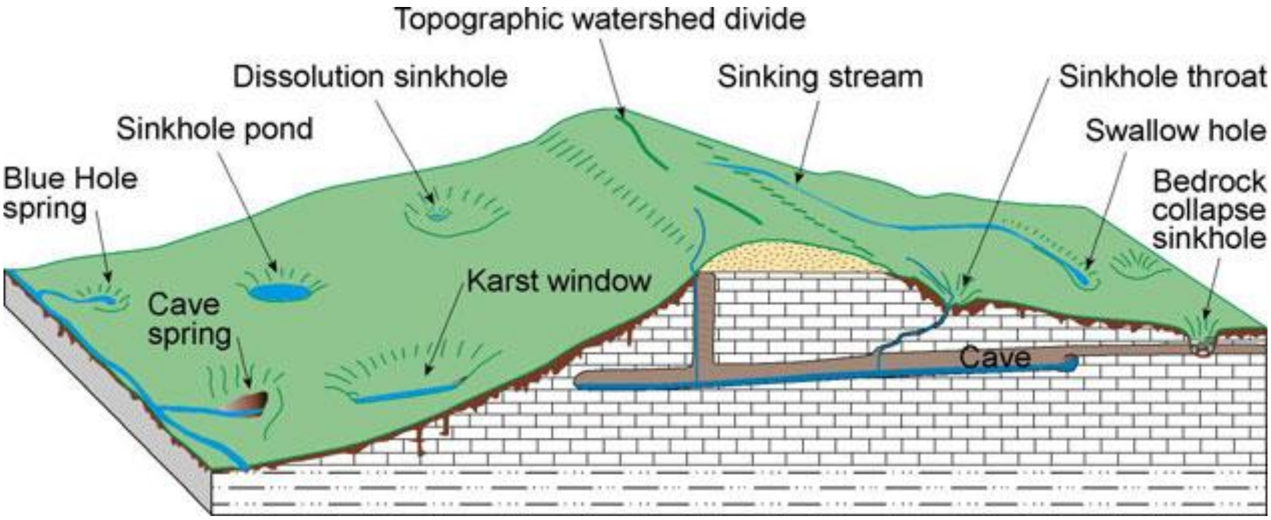
Karst Landscape

A karst landscape has sinkholes, sinking streams, caves, and springs. The term "karst" is derived from a Slavic word that means barren, stony ground. It is also the name of a region in Slovenia near the border with Italy that is well known for its sinkholes and springs. Geologists have adopted karst as the term for all such terrain. The term "karst" describes the whole landscape, not a single sinkhole or spring.

A karst landscape most commonly develops on limestone, but can develop on several other types of rocks, such as dolostone (magnesium carbonate or the mineral dolomite), gypsum, and salt. Precipitation infiltrates into the soil and flows into the subsurface from higher elevations and generally toward a stream at a lower elevation. Weak acids found naturally in rain and soil water slowly dissolve the tiny fractures in the soluble bedrock, enlarging the joints and bedding planes.

Fifty-five percent of Kentucky sits atop carbonate rocks that are prone to developing karst. Karst hazards include sinkhole flooding, sudden cover collapse, and leakage around dams. The estimated damage caused by karst hazards every year in Kentucky is between $0.5 million and $1 million.

Below is a schematic diagram of karst terrain in Kentucky.



Generalized block diagram showing typical karst landscape in Kentucky.
Other types of karst features occur that are not illustrated.

Karst as Geologic Hazard

A geologic hazard is a naturally occurring geologic condition that may result in property damage or is a threat to the safety of people. Many hazards to man-made structures can be associated with the type of bedrock, the presence of faults, and other earth processes that occur in Kentucky. Earthquakes get the most press coverage and are the most notorious. Annually, landslides, shrink-swell soils, and flooding cause more damage than earthquakes in Kentucky because they happen more often. Karst hazards cause less damage than earthquakes or landslides, perhaps $500,000 to $2,000,000 of economic loss annually, but can still have devastating effect on properties, infrastructures and people.

Four geologic hazards are associated with karst.

- Two common karst-related geologic hazards -- cover-collapse sinkholes and sinkhole flooding -- cause the most damage to buildings.
- A third karst hazard is relatively high concentrations of radon, sometimes found in basements and crawl spaces of houses built on karst.
- Finally, the hydrogeology of karst aquifers makes the groundwater vulnerable to pollution, and this vulnerability may also be considered a type of geologic hazard.

Land subsidence occurs when large amounts of ground water have been withdrawn from certain types of rocks, such as fine-grained sediments. The rock compacts because the water is partly responsible for holding the ground up. When the water is withdrawn, the rock falls in on itself. Land subsidence can occur unnoticed because it covers large areas rather than in a small spot, like a sinkhole. Subsidence not only damages structures built immediately above the subsiding area, but also sets up lateral stresses that may severely damage adjacent structures.

Sinkhole Types

- *Cover-Collapse Sinkholes* occur in the soil or other loose material overlying soluble bedrock. Sinkholes that suddenly appear form in two ways. I
  - In the first way, the bedrock roof of a cave becomes too thin to support the weight of the bedrock and the soil material above it. The cave roof then collapses, forming a bedrock-collapse sinkhole. Bedrock collapse is rare and the least likely way a sinkhole can form, although it is commonly incorrectly assumed to be the way all sinkholes form.
  - The second way sinkholes can form is much more common and much less dramatic. The sinkhole begins to form when a fracture in the limestone bedrock is enlarged by water dissolving the limestone. As the bedrock is dissolved and carried away underground, the soil gently slumps or erodes into the developing sinkhole. Once the underlying conduits become large enough, insoluble soil and rock particles are carried away too.

  Cover-collapse sinkholes can vary in size from 1 or 2 feet deep and wide, to tens of feet deep and wide. The thickness and cohesiveness of the soil cover determine the size of a cover-collapse sinkhole.
- *Solution sinkholes* result from increased groundwater flow into higher porosity zones within the rock, typically through fractures or joints within the rock. An increase of slightly acidic surface water into the subsurface continues the slow dissolution of the rock matrix, resulting in slow subsidence as surface materials fill the voids.
- *Raveling sinkholes* form when a thick overburden of sediment over a deep cavern caves into the void and pipes upward toward the surface. As the overlying material or "plug" erodes into the cavern, the void migrates upward until the cover can no longer be supported and then subsidence begins.

Sinkhole Flooding

Sinkhole flooding is a naturally occurring event that usually follows the same storms that cause riverine flooding, so it is often not recognized as Karst-related. Flood events will differ not only because of the amount of precipitation, but also because the drainage capacity of individual sinkholes can change, sometimes very suddenly, as the Karst landscape evolves. Sinkholes can also flood when their outlets are clogged, preventing water from being carried away as fast as it flows in. Trash thrown into a sinkhole can clog its throat, as can soil eroded from fields and construction sites, or a natural rock fall near the sinkhole's opening. Sometimes the conduit itself is too narrow because it has recently (in the geologic sense) captured a larger drainage basin. The reach of a conduit downstream from constriction could carry a higher flow than it is receiving were it not for this restriction.

Sinkholes flood more easily around development (roofs, parking lots, highways), which increases both the total runoff and the rapidity of runoff from a storm. Another reason that sinkholes flood is back-flooding, the outcome when the discharge capacity of the entire Karst conduit network is exceeded. Some up-gradient sinkholes that drain normally during the short, modest accumulation of storms may actually become springs that discharge water during prolonged rainfall.

Land Surface Indicators of Sinkhole Collapse

- Circular and linear cracks in soil, asphalt, and concrete paving and floors
- Depressions in soil or pavement that commonly result in ponds of water
- Slumping, sagging, or tilting of trees, roads, rails, fences, pipes, poles, sign boards, and other vertical or horizontal structures
- Downward movement of small-diameter vertical or horizontal structures
- Fractures in foundations and walls, often accompanied by jammed doors and windows
- Small conical holes that appear in the ground over a relatively short period of time
- Sudden muddying of water in a well that has been producing clear water
- Sudden draining of a pond or creek

3.10.1 Karst/Sinkhole Profile

SUMMARY OF KARST/SINKHOLE RISK FACTORS

Period of occurrence:	At any time
Number of Events to-date:	Unknown. 451 mapped sinkholes
Probability of event(s):	No data
Warning time:	Weeks to months, according to monitoring or maintenance.
Potential Impact(s):	Economic losses such as decreased land values and Agro-business losses. May cause minimal to severe property damage and destruction. May cause geological movement, causing infrastructure damages.
Past Damages:	No data

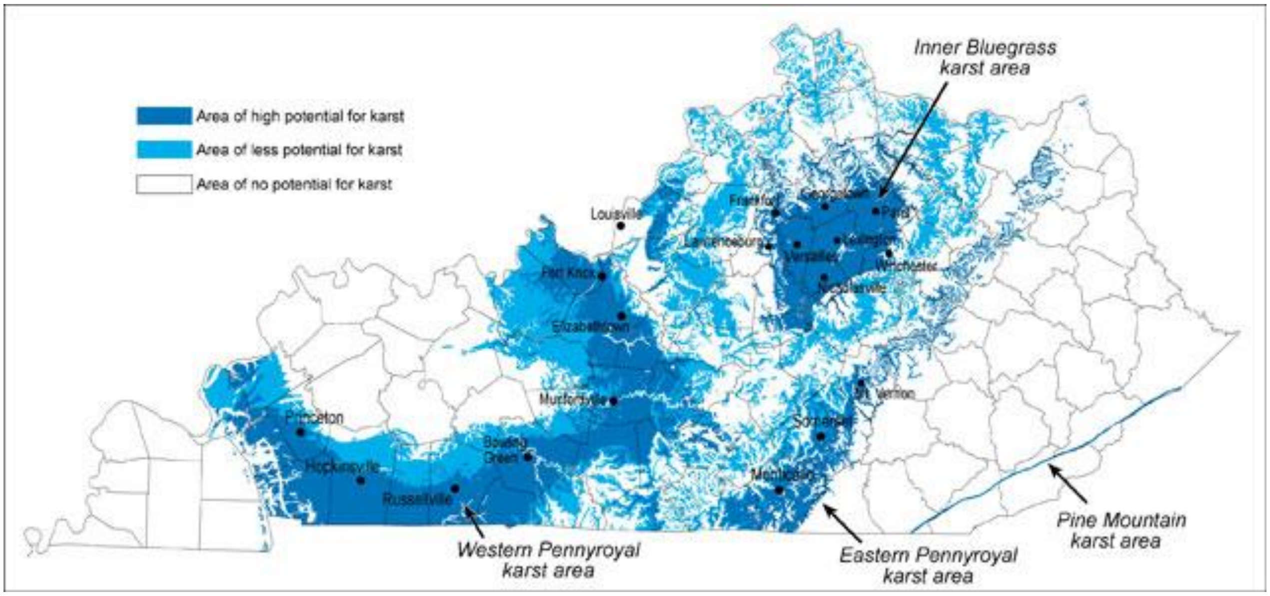
Background: Karst landscapes and aquifers form when water dissolves limestone, gypsum, and other rocks. The surface expression of Karst includes sinkholes, sinking streams and springs. Karst hazards include: sinkhole flooding, sudden cover collapse, leakage around dams, and collapse of lagoons resulting in waste spills and radon infiltration into homes. Sinkholes are among the most common problems of living in a karst area.

In Kentucky

About 38% of the state has sinkholes that are recognizable on topographic maps, and 25% has obvious and well-developed Karst features. Much of the state's beautiful scenery is a direct result of the development of a Karst landscape.

Kentucky is one of the most famous karst areas in the world. Much of the state's beautiful scenery, particularly the horse farms of the Inner Bluegrass, is the result of development of karst landscape. The karst topography of Kentucky is mostly on limestone, but also some dolostone. The areas where those rocks are near the surface closely approximate where karst topography will form.

The map below shows the outcrop of limestone and dolostone and closely represents the karst areas. The bedrock is millions of years old, and the karst terrain formed on them is hundreds of thousands of years old. In humid climates such as Kentucky's, it may be assumed that all limestone has karst development, although that development may not be visible at the surface.



Generalized map of the karst regions of Kentucky. The darker blue areas are highly karstic, and the lighter blue areas are less karstic by KGS.
Source: www.esri.com/news/arcnews/winter0203articles/winter0203gifs/p31p1-1g.jpg

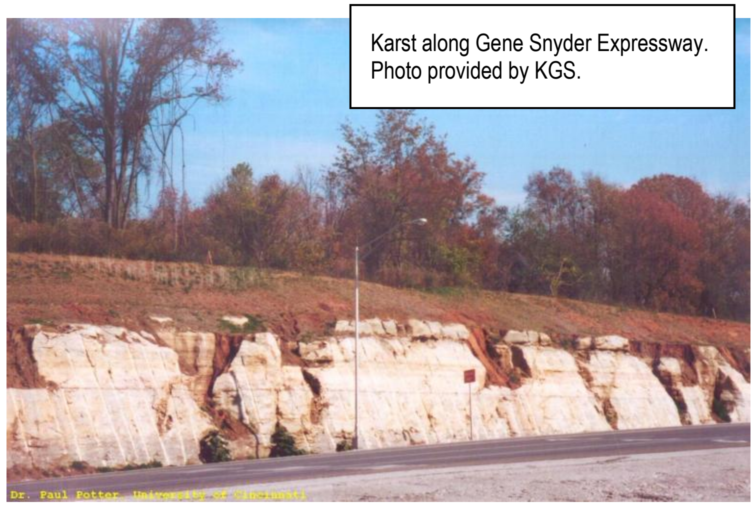
The outcrop area of the limestone bedrock in Kentucky has been used to estimate the percentage of karst terrain or topography in the state. About 55 percent of Kentucky is underlain by rocks that could develop karst terrain, given enough time. About 38 percent of the state has at least some karst development recognizable on topographic maps, and 25 percent of the state is known to have well-developed karst features. Some Kentucky cities located on karst include (in the Inner Bluegrass) Frankfort, Louisville, Lexington, Lawrenceburg, Georgetown, Winchester, Paris, Versailles, and Nicholasville; (in the Western Pennyroyal) the communities of Fort Knox, Bowling Green, Elizabethtown, Munfordville, Russellville, Hopkinsville, and Princeton; (in the Eastern Pennyroyal) Somerset, Monticello, and Mount Vernon.

Historical Impact: Kentucky contains one of the world's largest Karst-ridden topographies. Springs and wells in Karst areas supply water to tens of thousands of homes. Much of Kentucky's prime farmland is underlain by Karst, as is a substantial amount of the Daniel Boone National Forest with its important recreational and timber resources.

Caves are also important Karst features, providing recreation and unique ecosystems. Mammoth Cave is the longest surveyed cave in the world, with more than 350 miles of passages. Two other caves in the state stretch more than 30 miles, and nine Kentucky caves are among the 50 longest caves in the U.S.

The most noticeable hazards in Kentucky are sinkhole flooding and cover collapse. Soil collapses are common in karst terrain, where water drains to caves through fissures in the bedrock. Over time, domes of soil form over these fissures and new development increases the drainage into these fissures, forming a sinkhole. Unfortunately, collapses are seldom reported to any central agency.

Karst Potential Impact in Louisville:
Damage to infrastructure from sinkhole flooding and cover collapse is so common in Kentucky that it is typically dealt with by local authorities as a routine matter. Throughout the state, many reservoirs of all sizes have leaking dams or leakage through carbonate bedrock around the dam. Louisville Metro is vulnerable to karst and sinkhole flooding. Following is a map of the sinkholes and karst areas in Louisville Metro.



Karst along Gene Snyder Expressway. Photo provided by KGS.

Strategies to Avoid Sinkhole Collapse

- Karst areas should be mapped thoroughly to help identify buried sinkholes and fracture trends. Geophysical methods, aerial photography, and digitally enhanced multi-spectral scanning can identify hidden soil drainage patterns, stressed vegetation, and moisture anomalies in soils over sinkholes.
- In large sinkholes, use bridges, pilings, pads of rock, concrete, special textiles, paved ditches, curbs, grouting, flumes, overflow channels, or a combination of methods to provide support for roads and other structures.
- Large buildings should not be built above domes in caves.

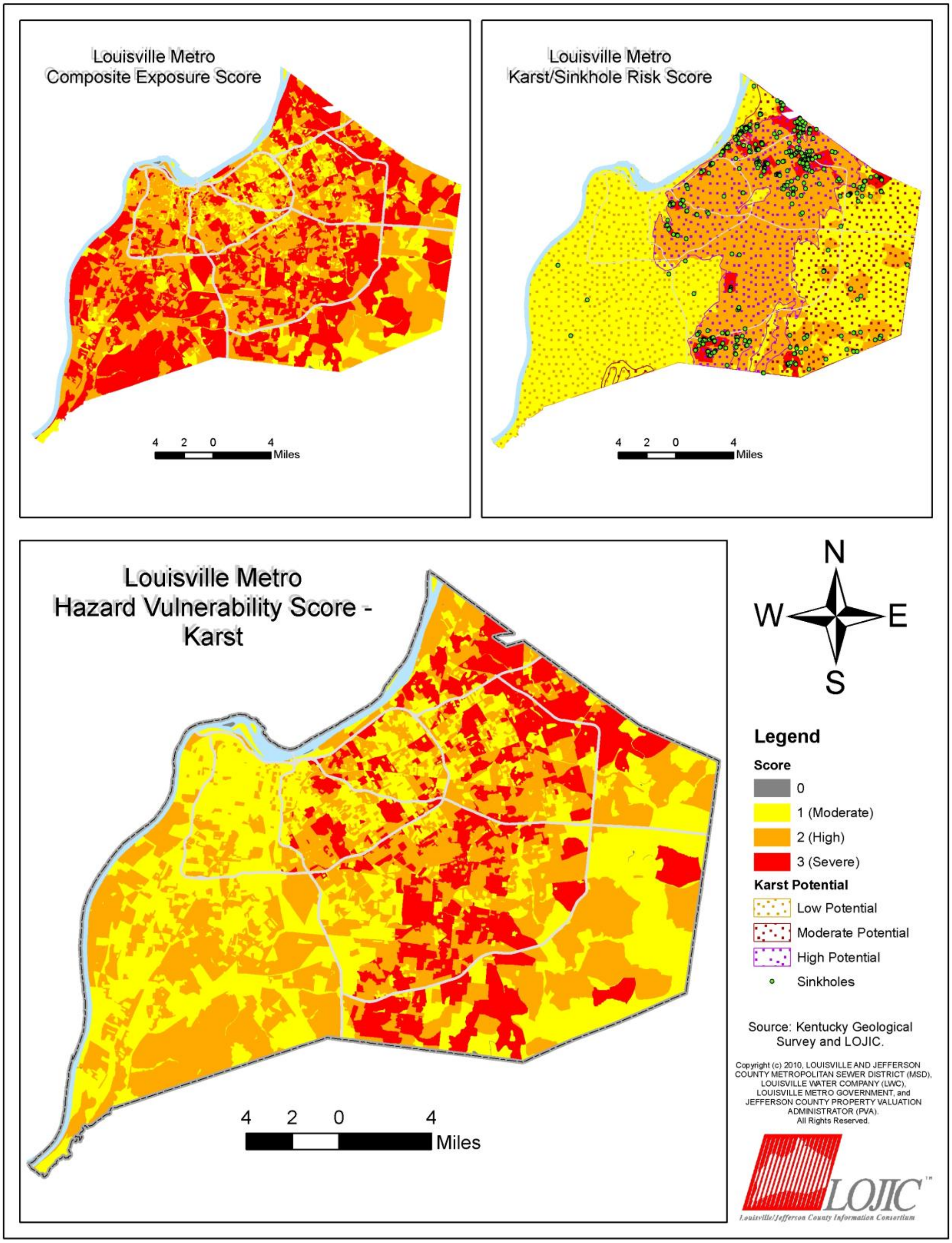
Karst: Cover-collapse sinkhole
soil and regolith fall into underground system. Photo provided by KGS.

3.10.1.1 Assessing Vulnerability Overview: Karst/Sinkhole

Karst/Sinkhole Vulnerability Score = Exposure Score X Risk Score

Assessing vulnerability by census block was determined through creating the Karst/Sinkhole Risk Score adding the Occurrence Rank and Area Affected Rank. The Occurrence Rank was determined by counting the number of Sinkholes located within each census block. The Occurrence Rank provided an understanding of where high concentrations of sinkholes are located within the community, thus producing areas of risk. The census blocks were then ranked 0 to 3 (0 = No data, 1 = Moderate, 2 = High, and 3 = Severe). The Area Affected Rank was calculated by taking the percent of the census block affected by the Kentucky Geological Survey (KGS) Karst potential map. The percentage of area affected by the Karst potential area was then calculated and ranked 0 to 3 (0 = No data, 1 = Moderate, 2 = High, and 3 = Severe). Next, the Karst/Sinkhole Occurrence Rank and Area Affected Rank scores were added together to produce the Karst/Sinkhole Risk Score.

The Karst/Sinkhole Vulnerability Score was calculated for each census block by multiplying the census block's Exposure Score by its Karst/Sinkhole Risk Score.


Louisville Metro
Composite Exposure Score
4 2 0 4
Miles
Louisville Metro
Karst/Sinkhole Risk Score
4 2 0 4
Miles
Louisville Metro
Hazard Vulnerability Score -
Karst
4 2 0 4
Miles
N
W
E
S
Legend
Score
0
1 (Moderate)
2 (High)
3 (Severe)
Karst Potential
Low Potential
Moderate Potential
High Potential
Sinkholes
Source: Kentucky Geological Survey and LOJIC.
Copyright (c) 2010, LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT (MSD), LOUISVILLE WATER COMPANY (LWC), LOUISVILLE METRO GOVERNMENT, and JEFFERSON COUNTY PROPERTY VALUATION ADMINISTRATOR (PVA). All Rights Reserved.
LOJIC
Louisville/Jefferson County Information Consortium

3.10.1.2 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: Karst/Sinkhole

In order to determine structures that are vulnerable and estimated to be damaged during a Karst/Sinkhole event the Project Staff used the Hazard Boundary Overlay methodology. The Hazard Boundary used as the overlay was the KGS Karst potential map. This Karst potential map displays areas located within high Karst risk zones, thus displaying areas where potential losses from sinkholes could occur.

The following table describes the total number of structures identified within the hazard boundary and the replacement cost of those structures. This model estimates complete damage of each structure located within the Hazard Boundary.

KARST/SINKHOLE	STRUCTURES
COMMERCIAL	7,463
INDUSTRIAL	532
RESIDENTIAL	108,470
OTHER	5,363
TOTAL BUILDINGS	**121,828**
ESTIMATED LOSSES	**$21,328,774,738**

3.11 Landslide

> **In the U. S.**
>
> Landslides cause $1 to 2 billion dollars in damages and more than 25 deaths on overage each year.

Description: Landslides occur when masses of rock, earth, or debris move down a slope. Landslides may be very small or very large, and can move at slow to very high speeds. Many landslides have been occurring over the same terrain since prehistoric times. They are activated by storms and fires and by human modification of the land. New landslides occur because of rainstorms, earthquakes, volcanic eruptions, and various human activities.

Mudflows or debris flows differ from landslides because they are rivers of rock, earth, and other debris saturated with water. Mudflows develop when water rapidly accumulates in the ground, such as during heavy rainfall or rapid snowmelt, changing the earth into a flowing river of mud or "slurry". A slurry can flow rapidly down slopes or through channels, and can strike with little or no warning at avalanche speeds. A slurry can travel several miles from its source, growing in size as it picks up trees, cars, and other materials along the way. Landslides pose serious threats to highways and structures that support fisheries, tourism, timber harvesting, mining, and energy production, as well as general transportation.

Most losses from landslides and soil creep occur in cities developed on gently sloping hillsides. Although a landslide may occur almost anywhere, from man-made slopes to natural, pristine ground, most slides occur in areas that have experienced sliding in the past. All landslides are triggered by similar causes. These can be weaknesses in the rock and soil, earthquake or volcanic activity, the occurrence of heavy rainfall or snowmelt, or construction activity changing some critical aspect of the geological environment. Landslides that occur following periods of heavy rain or rapid snowmelt worsen the accompanying effects of flooding.

Areas that are generally prone to landslide hazards include existing old landslides; the bases of steep slopes; the bases of drainage channels; and developed hillsides where leach-field septic systems are used.

Areas that are typically considered safe from landslides include areas that have not moved in the past; relatively flat-lying areas away from sudden changes in slope; and areas at the top or along ridges, set back from the tops of slopes.

Landslide Types

- *Slides* of soil or rock involve downward displacement along one or more failure surfaces. The material from the slide may be broken into a number of pieces or remain a single, intact mass. Sliding can be rotational, where movement involves turning about a specific point. Sliding can be translational, where movement is down slope on a path roughly parallel to the failure surface. The most common example of a rotational slide is a slump, which has a strong, backward rotational component and a curved, upwardly-concave failure surface.

- *Flows* are characterized by shear strains distributed throughout the mass of material. They are distinguished from slides by high water content and distribution of velocities resembling that of viscous fluids. Debris flows are common occurrences in much of North America. These flows are a form of rapid movement in which loose soils, rocks, and organic matter, combined with air and water, form a slurry that flows downslope. The term "debris avalanche" describes a variety of very rapid to extremely rapid debris flows associated with volcanic hazards. Mudflows are flows of fine-grained materials, such as sand, silt, or clay, with high water content. A subcategory of debris flows, mudflows contains less than 50 percent gravel.
- *Lateral spreads* are characterized by large elements of distributed, lateral displacement of materials. They occur in rock, but the process is not well-documented and the movement rates are very slow. Lateral spreads can occur in fine-grained, sensitive soils such as quick clays, particularly if remolded or disturbed by construction and grading. Loose, granular soils commonly produce lateral spread through liquefaction. Liquefaction can occur spontaneously, presumably because of changes in pore-water pressures, or in response to vibrations such as those produced by strong earthquakes.
- *Falls* and *Topples*. Falls occur when masses of rock or other material detach from a steep slope or cliff and descend by free fall, rolling, or bouncing. These movements are rapid to extremely rapid and are commonly triggered by earthquakes. Topples consist of forward rotation of rocks or other materials about a pivot point on a hill slope. Toppling may culminate in abrupt falling, sliding, or bouncing, but the movement is tilting without resulting in collapse. Data on rates of movement and control measures for topples is sparse.

Slope failures are major natural hazards in many areas throughout the world. Slope failures are also referred to as *mass movements.* A slope failure is classified based on how it moves and the type of material being moved.

Five major types of slope failures have been identified:

- *Creep:* very slow movement of rock or soil downslope.
- *Falls:* very rapid fall of rock and earth material from vertical or near vertical slopes.
- *Flows:* slow to rapid movement of rock, soil, snow, or ice. Types of flows include mudflows, earthflows, debris flows, and snow avalanches.
- *Slides:* Very slow to very rapid movement of soil or rock. This category includes rockslides, earth slides, and slumps.
- *Subsidence:* slow to very rapid collapse of rock or soil into underlying spaces. Sinkholes in Karst/Sinkhole landscapes are a common example.

3.11.1 Landslide Profile

SUMMARY OF LANDSLIDE RISK FACTORS

Period of occurrence:	At any time. Chance of occurrence increases after heavy rainfall, snowmelt, or construction activity.
Number of Events to-date 1990-2009	7
Probability of event(s):	0.35
Warning time:	Weeks to months, depends on inspection for weaknesses in rock and soil. Some landslides move slowly and cause damage gradually, whereas others move so rapidly that they can destroy property and take lives suddenly and unexpectedly.
Potential Impact(s):	Economic losses such as decreased land values, Agro-business losses, disruption of utility and transportation systems, and costs for any litigation. May cause geological movement, causing infrastructure damages ranging from minimal to severe.
Past Damages:	$98,851

Background: Gravity is the force driving landslide movement. Factors that allow the force of gravity to overcome the resistance of earth material to landslide movement include: saturation by water, steepening of slopes by erosion or construction, alternate freezing or thawing, and earthquake shaking. Population increase, rapid urbanization, and development will cause an increasing trend in landslide activity.

In Kentucky

Since the early 70s, there have been over 3,000 landslide locations reported by the Kentucky Transportation Cabinet. However, there are many landslides that are unrelated to roads or highway construction and go unreported.

Kentucky Landslide History

For Kentucky, KGS reports a large landslide in Hickman, in western Kentucky, destroyed many houses, and more than $10 million has been spent to try to fix it. About $1 million has been spent to repair damage caused by landslides on the Audubon Parkway between Owensboro and Henderson.

In many locations, both geologic and atmospheric processes may play a role in the movement of a slope. Slope failures can occur in any season, but are more likely to be triggered by weather events such as rain, snow, or freezing and thawing of soil water. With the exception of slope failures triggered by geologic processes, most slope failures occur between spring and fall.

- In early spring, snowmelt can increase pore pressures in the soil, increasing the risk of slope failures.

- During summer and fall, intense or prolonged rainfall can trigger slope failures.
- Freeze-thaw events, which usually happen during spring and fall but also during warm winters, can increase the potential for slope failure.

Potential Costs

Public and private economic losses from landslides include not only the direct costs of replacing and repairing damaged facilities, but also the indirect cost associated with lost productivity, disruption of utility and transportation systems and costs for any litigation. Other indirect costs may include loss of tax revenue on property devalued because of landslides, loss of real estate value in landslide-prone areas, and environmental effects such as water quality. Some indirect costs are difficult to evaluate, thus estimates are usually conservative or simply ignored. If indirect costs were realistically determined, they likely would exceed direct costs.

Landslide along a cutbank in the Kentucky River in Jessamine Co. along KY 1541. Failure occurred on April 12th 2009 after heavy rains affecting 150 ft of the shoulder on the road. The road was shut down for several days. The slide material consists of roadbed fill overlying weathered rock and soil.

Photo by Matt Crawford, KGS

Much of the economic loss is borne by Federal, State, and local agencies responsible for disaster assistance, and highway maintenance and repair. Flood insurance does not cover landslides. Private costs involve mainly damage to land and structures. A severe landslide can result in financial ruin for the property owners because landslide insurance (except for debris flow coverage) or other means of spreading the costs of damage are unavailable.

Landslide Potential Impact in Louisville Metro

Landslides are more likely to occur in the southwest portion of Louisville Metro. Probability increases at the base of a steep slope; the base of a drainage channel; and developed hillsides where leach-field septic systems are used. Several studies have shown that almost any modification of a slope by people increases the risk of slope movement, especially in areas already susceptible.

Landslide problems are usually related to certain rock formations that yield soils that are unstable on moderate to steep slopes. Often, slopes are cut into or oversteeped to create additional level land for development. Individuals can take steps to reduce their personal risk.

- Steep slopes are more susceptible to landslides and should be avoided when choosing a building site.

- Slope stability decreases as water moves into the soil. Springs, seeps, roof runoff, gutter down spouts, septic systems, and site grading that cause ponding or runoff are sources of water that often contribute to landslides.
- Changing the natural slope by creating a level area where none previously existed adds weight and increases the chance of a landslide.
- Poor site selection for roads and driveways.
- Improper placement of fill material.
- Removal of trees and other vegetation. Plants, especially trees, help remove water and stabilize the soil with their extensive root systems.

Louisville Metro Landslide Potential

Unstable soils also contribute to landslide potential in Louisville Metro as shown on “Core Graphic 4” of the *Louisville and Jefferson County Comprehensive Plan*: Soil types that are subject to mass wasting such as creep, slump or even landslides and mudslides coincide with slopes over 6 percent and the presence of underlying shale bedrock. Listed below are the soil types that are considered unstable due to the presence of underlying shale. Any highly sloped area may be subject to unstable conditions regardless of the presence of underlying shale.

Louisville Metro Soil Types

HgD	Holston gravelly silt loam, 12 to 20 percent slopes
HgE	Holston gravelly silt loam, 20 to 30 percent slopes
MpD2	Memphis silt loam, 12 to 20 percent slopes, eroded
MpE2	Memphis silt loam, 20 to 30 percent slopes, eroded
RcE	Rockcastle silt loam, 15 to 30 percent slopes
ZaC2	Zanesville silt loam, 6 to 12 percent slopes, eroded
ZaD2	Zanesville silt loam, 12 to 20 percent slopes, eroded

Source: Soil Survey: Jefferson County, Kentucky, US
Department of Agriculture Soil Conservation Service (June 1966).

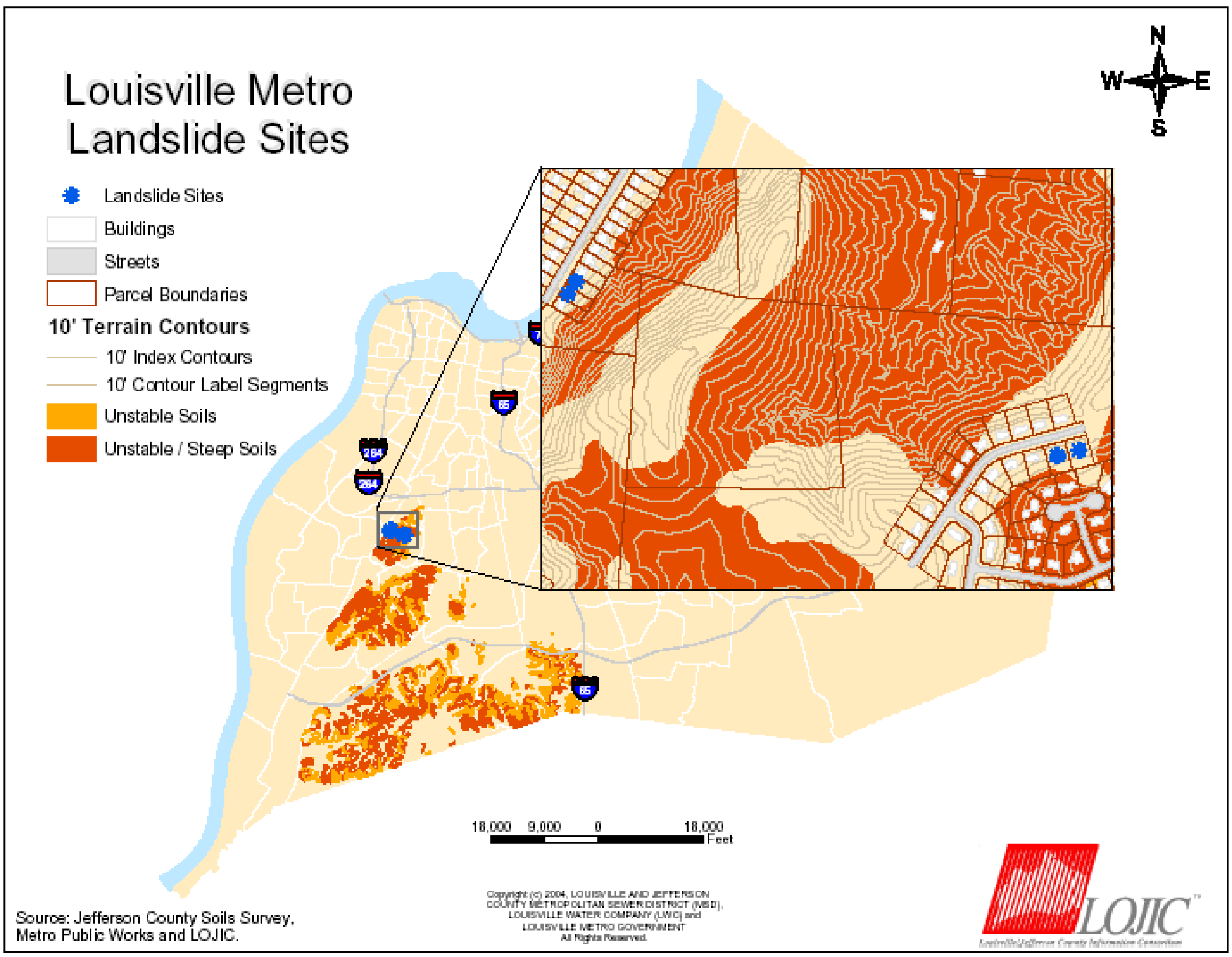
Louisville Metro Landslide History

No reports are available from USGS, NWS, NCDC, SHELDUS, or the State Mitigation Plan for landslide incidences. However, Louisville Metro has experienced landslides and slope failure affecting roads and infrastructure items. During the planning process, community members and community officials identified slope failure areas that have repeat occurrences.

The following unofficial reports of landslides are located in the vulnerable area of SW Louisville Metro (see map on next page).

- Louisville Metro Public Works reports two properties along Pine Mountain Road were acquired due to landslides; with estimated losses at around $150,000 each or $300,000 total.
- Public Works reports several properties (~60) along Cardinal Hill show signs of under-pinning.
- EMA reports, after the severe storm of 2003, 2 properties experienced minor to major landslide damage.
- Reports of landslides in Iroquois park, around Mitchell Hill, are commonly known for eroding.
- Geologic experts provided data of landslide events on Louisville Metro's highways (See Risk Score Map).

Following is a map of the areas vulnerable to landslide in Louisville Metro. The inset shows areas in the southwest portion of the area where landslides have occurred.



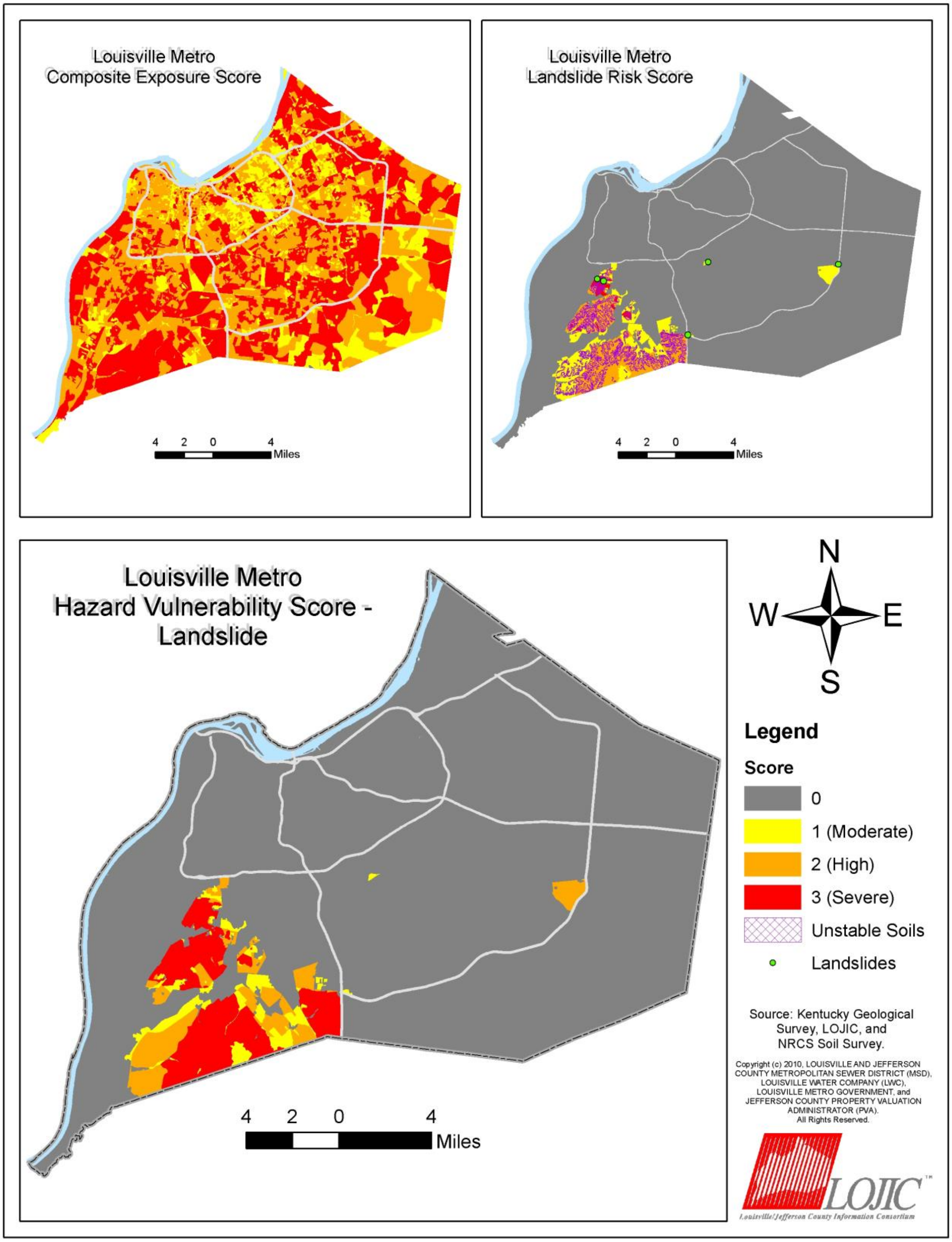
Landslide Map, LOJIC 2005

3.11.1.1 Assessing Vulnerability Overview: Landslide

Landslide Vulnerability Score = Exposure Score X Risk Score

Assessing vulnerability by census block was determined through creating the Landslide Risk Score adding the Occurrence Rank and Area Affected Rank. The Occurrence Rank was determined by counting the number of Landslide events located within each census block. The Occurrence Rank provided an understanding of where high concentrations of landslides are located within the community, thus producing areas of risk. The data was derived from local knowledge of landslide events as well as landslide events occurring on our transportation routes. The census blocks were then ranked 0 to 3 (0 = No data, 1 = Moderate, 2 = High, and 3 = Severe). The Area Affected Rank was calculated by taking the percent of the census block affected by the unstable soil/slope map created by LOJIC. The percentage of area affected by the landslide potential area was then calculated and ranked 0 to 3 (0 = No data, 1 = Moderate, 2 = High, and 3 = Severe). Next, the Landslide Occurrence Rank and Area Affected Rank scores were added together to produce the Landslide Risk Score.

The Landslide Vulnerability Score was calculated for each census block by multiplying the census block's Exposure Score by its Landslide Risk Score.


Louisville Metro
Composite Exposure Score
4 2 0 4
Miles
Louisville Metro
Landslide Risk Score
4 2 0 4
Miles
Louisville Metro
Hazard Vulnerability Score - Landslide
4 2 0 4
Miles
N
W
E
S
Legend
Score
0
1 (Moderate)
2 (High)
3 (Severe)
Unstable Soils
Landslides
Source: Kentucky Geological Survey, LOJIC, and NRCS Soil Survey.
Copyright (c) 2010, LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT (MSD), LOUISVILLE WATER COMPANY (LWC), LOUISVILLE METRO GOVERNMENT, and JEFFERSON COUNTY PROPERTY VALUATION ADMINISTRATOR (PVA).
All Rights Reserved.
LOJIC
Louisville/Jefferson County Information Consortium

3.11.1.2 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: Landslide

In order to determine structures that are vulnerable and estimated to be damaged during a Landslide event the Project Staff used the Hazard Boundary Overlay methodology. The Hazard Boundary used as the overlay was the unstable soil/slope map or Landslide potential map. This Landslide potential map displays areas where there are unstable soils and steep slopes, thus displaying areas where potential losses from Landslides could occur.

The following table describes the total number of structures identified within the hazard boundary and the replacement cost of those structures. This model estimates complete damage of each structure located within the Hazard Boundary.

LANDSLIDE	STRUCTURES
COMMERCIAL	96
INDUSTRIAL	4
RESIDENTIAL	2,417
OTHER	99
TOTAL BUILDINGS	**2,616**
ESTIMATED LOSS	**$350,252,067**

3.12 Severe Storm

Descriptions:

A thunderstorm is formed from a combination of moisture, rapidly rising warm air, and a force capable of lifting air such as a warm and cold front, a sea breeze or a mountain. All thunderstorms contain lightning and may occur singly, in clusters or in lines. Thus, it is possible for several thunderstorms to affect one location in the course of a few hours. Some of the most severe weather occurs when a single thunderstorm affects one location for an extended period time. The NWS considers a thunderstorm as severe if it develops ¾ inch hail or 50-knot (58 mph) winds.

Lightning is an electrical discharge that results from the buildup of positive and negative charges within a thunderstorm. When the buildup becomes strong enough, lightning appears as a "bolt". This flash of light usually occurs within the clouds or between the clouds and the ground. A bolt of lightning reaches a temperature approaching 50,000 degrees Fahrenheit in a split second. The rapid heating and cooling of air near the lightning causes thunder.

In the U. S.

Thunderstorms affect relatively small areas as the average storm is 15 miles in diameter and lasts an average of 30 minutes. Nearly 1,800 thunderstorms are occurring at any moment around the world, however, of the estimated 100,000 thunderstorms that occur each year in the U. S. only about 10 percent are classified as severe.

Lightning is the second most frequent killer in the U.S. Each year, lightning is responsible for an average of 93 deaths (more than tornadoes), 300 injuries, and several hundred million dollars in damage to property.

Additional types of severe storms include *straight line winds*.
There are several terms that mean the same as straight-line winds and they are convective wind gusts, outflow and downbursts. Straight-line wind is wind that comes out of a thunderstorm. If these winds meet or exceed 58 miles per hours then the storm is classified as severe by the National Weather Service. These winds are produced by the downward momentum in the downdraft region of a thunderstorm.

Radar observers use the intensity of the radar echo to distinguish between rain showers and thunderstorms. Lightning detection networks routinely track cloud-to-ground flashes, and therefore thunderstorms.

Thunderstorms occur when clouds develop sufficient upward motion and are cold enough to provide the ingredients (ice and super cooled water) to generate and separate electrical charges within the cloud. The cumulonimbus cloud is the perfect lightning and thunder factory, earning its nickname, "thunderhead".

All thunderstorms are dangerous and capable of threatening life and property in localized areas. While thunderstorms and lightning can be found throughout the U. S., they are most likely to occur in the central and southern states. Thunderstorms can also produce large, damaging hail, which causes nearly $1 billion in damage to property and crops annually. Thunderstorms are also capable of producing tornadoes, wind, and heavy rain that can lead to flash flooding. Hail, floods, and tornado hazards are addressed as individual hazards in this section of the Plan.

Types of Thunderstorms

- *Single Cell* (pulse storms). Typically last 20-30 minutes. Pulse storms can produce severe weather elements such as downbursts, hail, some heavy rainfall, and occasionally weak tornadoes. This storm is light to moderately dangerous to the public and moderately to highly dangerous to aviation.
- *Multicell Cluster*. These storms consist of a cluster of storms in varying stages of development. Multicell storms can produce moderate size hail, flash floods, and weak tornadoes. This storm is moderately dangerous to the public and moderately to highly dangerous to aviation.
- *Multicell Line*. Multicell line storms consist of a line of storms with a continuous, well-developed gust front at the leading edge of the line. Also known as squall lines, these storms can produce small to moderate size hail, occasional flash floods, and weak tornadoes. This storm is moderately dangerous to the public and moderately to highly dangerous to aviation.
- *Supercell*. Even though it is the rarest of storm types, the supercell is the most dangerous because of the extreme weather generated. Defined as a thunderstorm with a rotating updraft, these storms can produce strong downbursts, large hail, occasional flash floods, and weak to violent tornadoes. This storm is extremely dangerous to the public and aviation.
- *Straight-line winds*, which in extreme cases have the potential to exceed 100 miles per hour, are responsible for most thunderstorm wind damage. One type of straight-line wind, the downburst, can cause damage equivalent to a strong tornado and can be extremely dangerous to aviation.

Thunderstorm Facts

- The NWS estimates more than 100,000 thunderstorms in the U. S. each year.
- In the last 25 years, severe storms have been involved in over 300 federal disasters.

3.12.1 Severe Storm Profile

SUMMARY OF SEVERE STORMS RISK FACTORS

Period of occurrence:	Spring, Summer and Fall
Number of Events to-date 1957-2010:	169
Probability of event(s):	3.19
Warning time:	Minutes to hours
Potential Impact(s):	Utility damage and outages, infrastructure damage (transportation and communication systems), structural damage, fire, damaged or destroyed critical facilities, and hazardous material releases. Impacts human life, health, and public safety.
Past Damages:	$15,123,690

In Kentucky

Between 2000 to 2009, there were 19 Presidential Declarations due to severe storms and other storm-related events.

Background: The Midwest and Great Plains regions of the U.S. average between 40 and 60 days of thunderstorms per year. These two regions are prone to some of the most severe thunderstorms on Earth.

Potential Impacts of Severe Storms

Due to the destructive nature of thunderstorms and lightning these events impact human life, health, and public safety. The community is at-risk for: utility damage and outages, infrastructure damage (transportation and communication systems), structural damage, fire, damaged or destroyed critical facilities, and hazardous material releases.

Louisville Metro Severe Storm History

Louisville Metro has received six presidential declarations for severe storms, as shown in the following table.

DR #	Declaration Date	Disaster Type	# of KY Declared Counties
568	12/12/1978	Severe Storms, Flooding	37
821	2/24/1989	Severe Storms, Flooding	67
1471	6/3/2003	Landslide, Severe Storm, Tornado, Flooding	44
1523	6/10/04	Severe Storms, Tornadoes, Flooding, and Mudslides	78
1802	10/09/08	Severe Wind Storm Associated With Tropical Depression Ike	34
1855	08/14/09	Severe Storms, Straight-Line Winds, And Flooding	2

Between 2005 – 2010 there were 69 severe storms according to NCDC results. No deaths or injuries were reported during this time period. Fourteen storms caused property damage, ranging from $5 - 50K. Only one storm caused property damage of $50K. A narrative for this event is outlined below.

- **03 Apr 2007**: A tree was blown on to a house on Algonquin Parkway. Power lines were downed and a house suffered some roof damage near the intersection of Sixth Street and St. Catherine. A strong, late season cold front brought an end to an extended period of warm weather. It also brought severe storms to central Kentucky, including two confirmed tornadoes. $50K reported in Property Damage.

NWS Thunderstorm Reports

- **Since 1986** there have been 231 Severe Thunderstorm Warnings
- **Most in one day:** 5 on April 13, 2009
- **Since 1957** there have been 199 reports of winds of at least 58 mph in Jefferson County
- **Strongest:** 104 mph October 24, 2001 in the Okolona area
- **Fastest** Officially Measured Wind Gust: 84 mph April 3, 1974

However, there have been 3 Presidential Declaration since the writing of the 2005 Plan, as follows.

- **DR-1802 14 - September 2008:** The largest severe windstorm since the 1974 tornado caused by a Tropical Depression from Hurricane Ike hit the area with 80-mile an hour winds and effecting 1.8 million residents. Major Disaster Declaration number DR 1802 was declared on October 09, 2008. The impacts of the storm included extended power outages and extensive damage to trees and roofs.

  The impact to the electric distribution system was unprecedented in the area. In the Louisville area, 301,000 people lost power, which was a new record for the city. 1400 power lines were torn down, hundreds of power poles snapped, and 130 roads blocked by debris. Four people were killed by falling trees and limbs in Kentucky.

  Below are the damage estimates from DR 1802 - Wind in Louisville.

  Total Eligible Applicants - 55

  Total Projects (Project Worksheets) 138

  Category A - $4,492,356.71 /PWs = 43

  Category B - $1,494,405.96 /PWs = 41

  Category C - $167,363.58 /PWs = 1

  Category D - $0 /PWs = 0

  Category E - $426,596.70 /PWs = 40

  Category F - $2,139.64 /PWs = 2

  Category G - $46,189.99 /PWs = 11

  Total Project Amount: $6,629.052.58

- **DR-1841- 20 May 2009:** Starting on May 3, 2009, strong storms producing tornadoes, severe thunderstorms, heavy rainfall, flash flooding, and generalized flooding moved across the central and eastern parts of the Commonwealth resulting loss of life and private property and road closures and these conditions endangered public health and safety and threatened public and private property. There were over half a million citizens impacted by this event. FEMA estimates that total public assistance for this event will exceed $44 million. Over 5,543 applicants in four counties were awarded approximately $15 million in individual and household assistance.
- **DR-1855 -14 August 2009**: The counties of Jefferson and Trimble experienced a severe storm which contained straight-line winds and flooding. The flooding in Louisville was centralized in the downtown resulting in significant damages to the University of Louisville, the Louisville Public Library, several hospitals, and over a thousand private residences. Public Assistance is estimated to exceed $27 million dollars and over $17 million has been distributed in individual and household assistance.

3.12.2 Lightning

Types of Lightning

Lightning is a component of all thunderstorms. Flashes that do not strike the surface are called cloud flashes. They may be inside a cloud, travel from one part of a cloud to another, or from cloud to air. Lightning flashes can have more than one ground point. Roughly, there are five to ten times as many cloud flashes than cloud to ground flashes.

In the U.S.

During 2002-2004 U.S. fire departments responded annually to about 31,000 fires caused by lightning with $213,000,000 in direct property damages.

Source: NFPA Report, January 2008

Overall, there are four different types of lightning:

- Cloud to sky (sprites)
- Cloud to ground
- Intra-cloud
- Inter-cloud

Cloud to ground lightning can injure or kill people and destroy objects by direct or indirect means. Objects can either absorb or transmit energy. The absorbed energy can cause the object to explode, burn, or totally destruct.

The various forms of transfer are:

1) Tall object transferred to person
2) Tall object to ground to person
3) Object (telephone line, plumbing pipes) to a person in contact with the appliance

Injury and Death to People

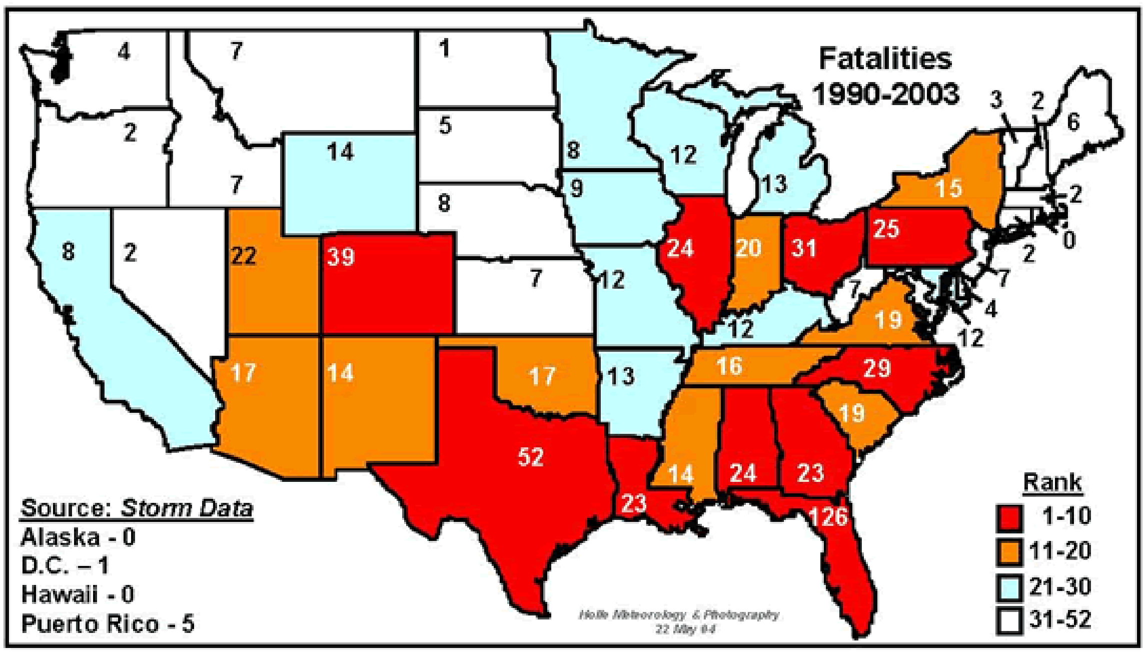
- 85% of lightning victims are children and young men ages 10 to 35.
- 25% of victims die and 70% of survivors suffer long-term effects.

Effects of Lightning

National Lightning Safety Institute (NLSI) 2008 research suggests realistic U.S. lightning costs and losses may exceed $5 to $6 billion per year.

- Forest fires - The period 2000-2006 showed 12,000 wild land fires started by lightning per year. This amounts to an average of 5.2 million acres annually. *Source: National Interagency Fire Center, 2007.*
- Fires to structures - 18% of all lumberyard fires and 30% of all church fires are lightning-related. *Source: Ohio Insurance Institute, Columbus OH.*

Number of Lightning Deaths in the United States, 1990-2003



Source: http://www.lightningsafety.com

Lightning Facts

- The peak temperature of lightning is around 60,000 degrees Fahrenheit, or about 5 times hotter than the surface of the Sun.
- Lightning most commonly occurs in thunderstorms, but it can also occur in snowstorms, sandstorms, and in the ejected material over volcanoes.
- Thirty percent of U.S. businesses suffer damage from lightning storms. *Source: Carnegie Mellon Report, 02/06.*

3.12.3 Lightning Profile

Local data and NCDC website archives show 8 lightning events between 2005 – 2010.

Location	Date	Time	Type	Death	Injuries	Property Damage
1. Fern Creek	05/19/2005	06:30 PM	Lightning	0	0	10K
2. Middletown	05/19/2005	06:40 PM	Lightning	0	0	10K
3. Fairdale	06/27/2007	18:30 PM	Lightning	0	0	20K
4. Jeffersontown	08/16/2007	16:37 PM	Lightning	0	0	10K
5. Audubon Park	07/08/2008	16:38 PM	Lightning	0	0	75K
6. Audubon Park	06/18/2009	10:15 AM	Lightning	0	0	15K
7. Audubon Park	08/04/2009	08:30 AM	Lightning	0	0	20K
8. Audubon Park	08/04/2009	09:09 AM	Lightning	0	0	200K
			TOTALS	**0**	**1**	**$522K**

The following event detail information describes various lightning events that caused damage and/or injury between 2004 – 2010, as listed above.

http://www.lightningsafety.com/

- **19 May 2005**, 2 events: Widespread reports of large hail, and a few more reports of non-severe hail in other locations. Flooding of low-lying areas, and streams flowing out of banks, also resulted from thunderstorms.
  - A lightning strike caused a house fire on Waters Edge Drive. Property Damage was estimated at $10K.
  - A lightning strike caused a house fire on Pepperdine Court. Property Damage was estimated at $10K.
- **25 May 2004**, 2 events:
  - A house fire started due to a lightning strike in the 6700 block of Green Manor Drive. Details of damage were unavailable. Property Damage was estimated at $10K.
  - Lightning blew a three foot hole in the side of a house. Fire caused moderate damage to the second floor and attic of the house. Property Damage was estimated at $20K.
- **27 May 2004**, A tree was struck by lightning and fell on a car, destroying it. Property Damage was estimated at $10K
- **27 June 2007**, Two houses were struck by lightning, and had attic damage due to fire. A weak upper level disturbance pushed some pulse thunderstorms above severe limits. Property Damage was estimated at $20K.

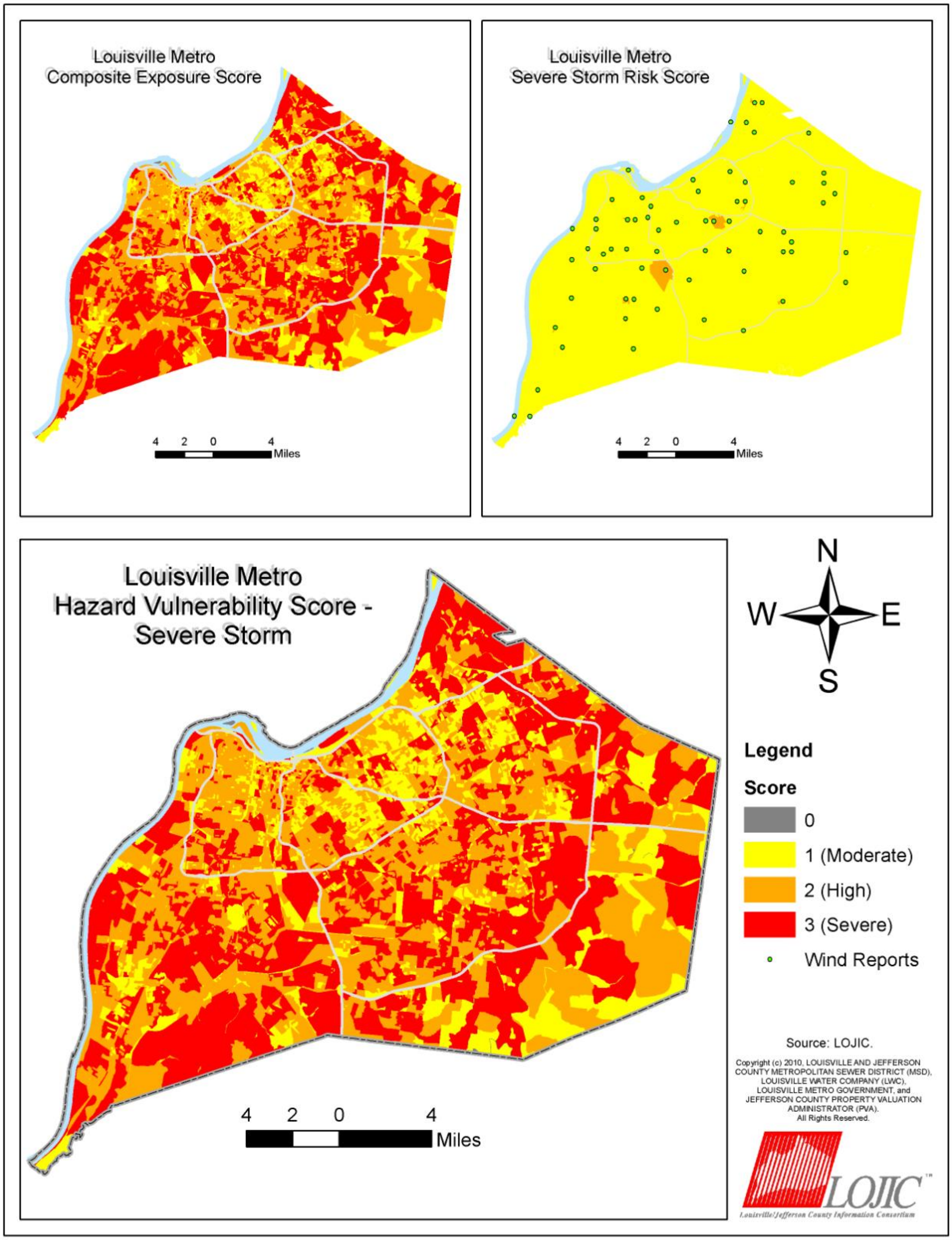
- **16 August 2007**, Lightning started a house fire in the Jeffersontown area. The extent of damage is unknown. Property Damage was estimated at $10K.
- **08 July 2008**, Lightning started a large house fire in the Lake Forest area. Two lines of thunderstorms brought damaging winds and small hail to the area. Lightning also caused a house fire. Property Damage was estimated at $74K.
- **18 June 2009**, Lightning struck two houses in the Jeffersontown area and caused several structural fires across the county. While damaging winds were the main event, some hail and lightning strikes causing fires were also reported. Property Damage was estimated at $15K.
- **04 August 2009**, Lightning started a four alarm apartment fire on Hurstbourne Parkway near I-64. Property Damage was estimated at $ 200K.

3.12.3.1 Assessing Vulnerability Overview: Severe Storm

Severe Storm Vulnerability Score = Exposure Score X Risk Score

Assessing vulnerability by census block was determined through creating the Severe Storm Risk Score using the Severe Storm Occurrence Rank. The Severe Storm Occurrence Rank was calculated using GIS point data provided by the NOAA Storm Prediction Center's SVRGIS datasets. These datasets geo-locate Severe Storm occurrences throughout the United States. The Project Staff took the national dataset and clipped it to Louisville Metro using a spatial analysis clip tool within GIS. The Severe Storm Occurrence Rank was then calculated by counting the number of occurrences within each census block and then ranked 0 to 3 (0 = No data, 1 = Moderate, 2 = High, and 3 = Severe). This model displayed the areas of high probability based on past events occurring in a particular location.

The Severe Storm Vulnerability Score was calculated for each census block by multiplying the census block's Exposure Score by its Severe Storm Risk Score.


Louisville Metro
Composite Exposure Score
Louisville Metro
Severe Storm Risk Score
Louisville Metro
Hazard Vulnerability Score - Severe Storm
4 2 0 4
Miles
N
W
E
S
Legend
Score
0
1 (Moderate)
2 (High)
3 (Severe)
Wind Reports
Source: LOJIC.
Copyright (c) 2010, LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT (MSD), LOUISVILLE WATER COMPANY (LWC), LOUISVILLE METRO GOVERNMENT, and JEFFERSON COUNTY PROPERTY VALUATION ADMINISTRATOR (PVA). All Rights Reserved.
LOJIC
Louisville/Jefferson County Information Consortium

3.12.3.2 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: Severe Storm

In order to determine structures that are vulnerable and estimated to be damaged during a Severe Storm event the Project Staff used the Hazard Boundary Overlay methodology. The Hazard Boundary used as the overlay was the Severe (3) census blocks. These Severe (3) census blocks identify areas of high probability for a Severe Storm event, thus was used to showcase areas of severe risk in this model.

The following table describes the total number of structures identified within the hazard boundary and the replacement cost of those structures. This model estimates complete damage of each structure located within the Hazard Boundary.

SEVERE STORM	STRUCTURES
COMMERCIAL	7,325
INDUSTRIAL	1,571
RESIDENTIAL	57,434
OTHER	5,055
TOTAL BUILDINGS	**71,385**
ESTIMATED LOSS	**$13,919,094,537**

3.13 Severe Winter Storm

Description: A winter storm can range from moderate snow over a few hours to blizzard conditions with blinding wind-driven snow, sleet and/or ice and extreme cold that lasts several days.

A severe winter storm is defined as an event that drops four or more inches of snow during a 12-hour period or six or more inches during a 24-hour span. Severe winter storms are fueled by strong temperature gradients and an active upper-level cold jet stream. Some winter storms may be large enough to affect several states while others may affect only a single community. Most winter storms are accompanied by low temperatures and blowing snow, which can severely reduce visibility.

In the U. S.

Every state in the continental U.S. and Alaska has been impacted by severe winter storms. The super-storm of March 1993 caused over $2 billion in property damage in twenty states and Washington D.C. At least 79 deaths and 600 injuries were attributed to the storm.

Snow and ice are threats to most of the U. S. during the northern hemisphere's winter, which begins December and ends in Spring. During the early and late months of the winter season, snow becomes warmer, giving it a greater tendency to melt on contact or stick to the surface. The beginning and end of the winter season also brings a greater chance of freezing rain and sleet.

Severe Winter Types

- *Blizzards* are by far the most dangerous of all winter storms. They are characterized by temperatures below twenty degrees Fahrenheit and winds of at least 35 miles per hour. In addition to the temperatures and winds, a blizzard must have a sufficient amount of falling or blowing snow. The snow must reduce visibility to one-quarter mile or less for at least three hours. With high winds and heavy snow, these storms can punish residents throughout much of the U.S. during the winter months each year. In mid-March of 1993, a major blizzard struck the Eastern U.S., including parts of Kentucky.

Blizzards

Snow does not have to be falling during a blizzard. Winds need to be 35 mph or greater for at least 3 hours to be officially called a blizzard.

- *Ice storms* occur when freezing rain falls from clouds and freezes immediately on impact. Ice storms occur when cold air at the surface is overridden by warm, moist air at higher altitudes. As the warm air advances and is lifted over the cold air, precipitation begins falling as rain at high altitudes then becomes super cooled as it passes through the cold air mass below, and, in turn, freezes upon contact with chilled surfaces at temperatures of 32º F or below. In extreme cases, ice may accumulate several inches thick, though just a thin coating is often enough to do severe damage.

Possible Effects

Freezing rain can result in extensive damage to utility lines and buildings while making any type of travel extremely dangerous. The results are sometimes devastating: entire states can be almost entirely without electricity and communication for several weeks. Winter storms can paralyze a community by shutting down normal day-to-day operations. Heavy snow can also lead to the collapse of weak roofs or unstable structures. Storm effects can cause hazardous conditions and hidden problems, including the following:

- *Power outages* result when snow and ice accumulate on trees causing branches and trunks to break and fall onto power lines. Blackouts vary in size from one street to an entire city. Loss of electric power means loss of heat for some residents, which poses a significant threat to human life, particularly the elderly.
- *Flooding* may occur after precipitation has accumulated and then temperatures rise once again, which melts snow and ice. In turn, as more snow and ice accumulate the threat of flooding increases.
- *Snow and ice accumulation on roadways* can cause severe transportation problems in the form of extremely hazardous roadway conditions.
- *Extreme cold* temperatures may lead to frozen water mains and pipes, damaged car engines, and prolonged exposure to cold resulting in frostbite.

Everyone is potentially at risk during winter storms. In terms of death due to severe winter storms, 70% of the deaths are related to automobile accidents. 25% of those deaths occur when people are caught out in the storm and die from exposure. Of all the deaths related to exposure to cold, 20% occur at home.

NWS Windchill Chart

Wind (mph)	Temperature (°F)																	
Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times: 30 minutes; 10 minutes; 5 minutes

$$\text{Wind Chill } (^\circ F) = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$$

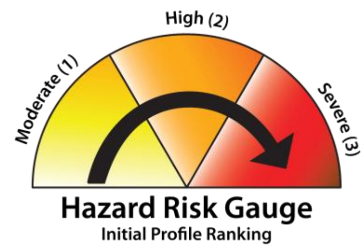
Where, T= Air Temperature (°F) V= Wind Speed (mph)

Effective 11/01/01

3.13.1 Severe Winter Storm Profile

SUMMARY OF SEVERE WINTER STORMS RISK FACTORS

Period of occurrence:	Winter
Number of Events to-date 1960-2010	47
Probability of event(s):	0.94
Warning time:	Days for snow Minutes to hours for ice.
Potential Impact(s):	Utility damage and outages, infrastructure damage (transportation and communication systems), structural damage, and damaged or destroyed critical facilities Can cause severe transportation problems and make travel extremely dangerous. Power outages, which results in loss of electrical power and potentially loss of heat, and human life. Extreme cold temperatures may lead to frozen water mains and pipes, damaged car engines, and prolonged exposure to cold resulting in frostbite.
Past Damages:	$11,623,777



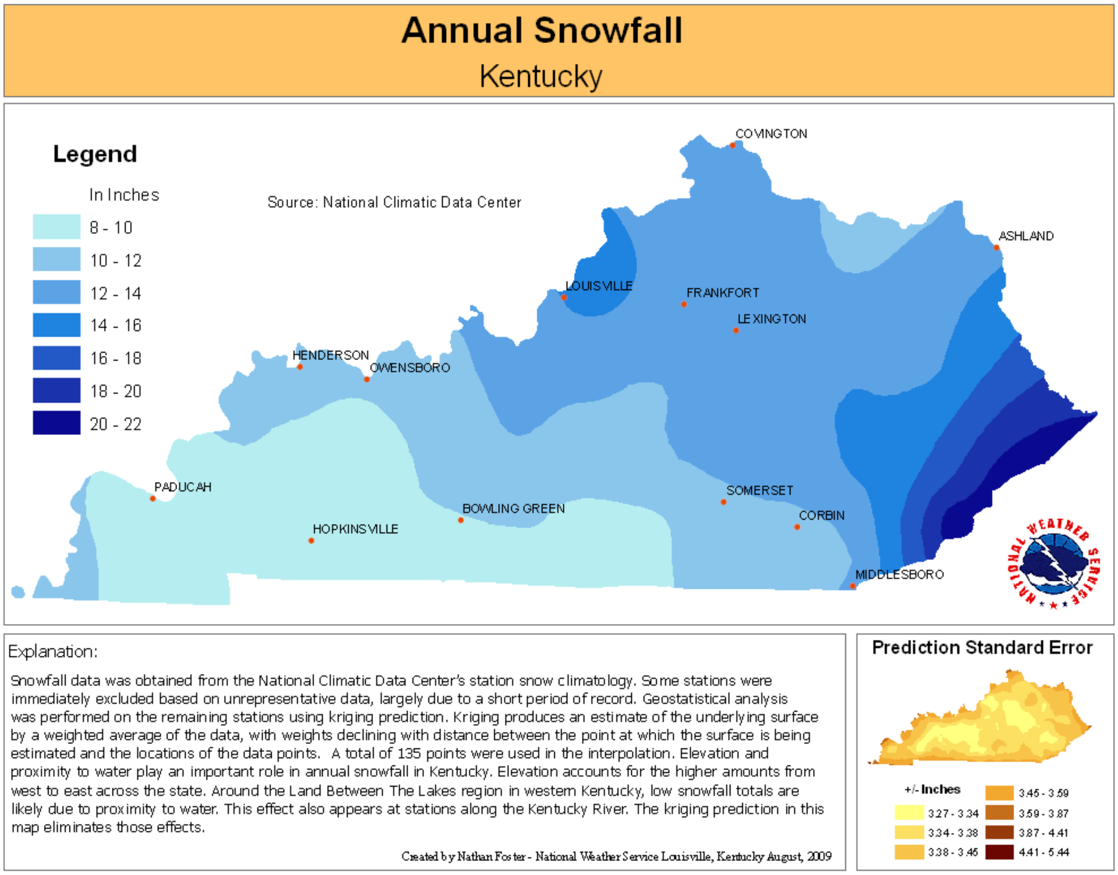
Background: Kentucky's location makes it vulnerable to heavy snowfall due to the state's proximity to the Gulf of Mexico, which provides a necessary moisture source, yet it is far enough north to be influenced by polar air masses. Low-pressure systems that bring heavy snow to Kentucky usually track eastward across the southern U.S. before turning toward the northeast. Frequently, these systems move up the east coast and have little effect on Kentucky. Sometimes, however, storms turn and move along the western margin of the Appalachian Mountains. With cold air in place over Kentucky, these storms bring moisture from the Gulf of Mexico and can dump heavy snow. During 1993- 2009, Kentucky received 7 Presidential Disaster Declarations due to severe winter weather.

In Kentucky

Since 1871 there have been nine calendar days on which 10 or more inches of snow have fallen

Heaviest 1-day snow: 15.5" January 17, 1994

Heaviest overall storm: 22.4" February 4-6, 1998



See the table for NWS normal snowfall totals for the Louisville area.

Month	Louisville Metro Normal Snowfall
January	5.1 inches
February	4.5 inches
March	2.2 inches
April	0.2 inches
May	0
June	0
July	0
August	0
September	0
October	0.1 inches
November	0.6 inches
December	2.0 inches

Potential Impact to Louisville Metro

Due to the destructive nature of snow and ice these events impact human life, health, and public safety. Community-wide impacts include: power outages, which results in loss of electrical power and potentially loss of heat, and human life. Extreme cold temperatures may lead to frozen water mains and pipes, damaged car engines, and prolonged exposure to cold resulting in frostbite. Community-wide impacts include: Utility damage and outages, infrastructure damage (transportation and communication systems), structural damage, and damaged or destroyed critical facilities. Can cause severe transportation problems and make travel extremely dangerous.

Historical Impact:

The level of impact severe winter weather will have upon a community greatly depends on its ability to manage and control its effects, such as the rapid mobilization of snow removal equipment. Louisville Metro has experienced several crippling winter storms over the years, which is common to the region due to its geographical location. It is expensive to acquire and maintain the necessary resources to combat winter's effects such as generators, snow removal equipment, and trucks. Preparedness includes, planning for emergency shelters and power outages.

Normal Precipitation	44.54 inches
Normal Number of Days with ≥ 0.01" Precipitation	126 days
Normal Number of Days with ≥ 1.00" Precipitation	11 days
Normal Snowfall	14.6 inches
Normal Number of Days with ≥ 0.1" Snow	11 days
Normal Number of Days with ≥ 1.0" Snow	4 days
Normal Number of Days with ≥ 2.0" Snow	2 days

Following is a table showing the Presidentially declared snow event in Louisville Metro.

Louisville Metro Presidentially Declared Snow/Ice Events

DR #	Declaration Date	Disaster Type	# of KY Declared Counties
1089	1/13/1996	Blizzard	120
1818	2/15/09	Severe Winter Storm and Flooding	103

(Source: FEMA)

Louisville Metro Historic Snow Events:

In Louisville Metro, severe winter weather conditions normally occur during the months of January and February. Following is NCDC event detail for eight Louisville Metro's snow winter storm events between 2005 – 2010.

	Location	Date	Time	Type	Mag	Death	Injury	Property Damage
1.	KYZ023 - 028>031 - 034>035 - 038	02/11/2008	16:00 PM	Winter Storm	N/A	0	0	10K
2.	KYZ025 - 030	02/21/2008	11:00 AM	Ice Storm	N/A	0	0	15K
3.	KYZ023>036 - 038>041 - 045 - 053 - 061>062 - 070	03/07/2008	07:00 AM	Heavy Snow	N/A	0	0	0K
4.	KYZ030 - 036	12/23/2008	13:30 PM	Winter Weather	N/A	0	0	80K
5.	KYZ023>026 - 030 - 074	01/27/2009	00:00 AM	Winter Storm	N/A	0	0	0K
6.	KYZ030>032 - 039 - 041	01/07/2010	07:00 AM	Winter Storm	N/A	0	0	0K
7.	KYZ030	01/29/2010	23:40 PM	Heavy Snow	N/A	0	0	0K
8.	KYZ030	02/08/2010	23:30 PM	Heavy Snow	N/A	0	0	0K
					TOTALS	**0**	**0**	**205K**

Following is a description of the above listed events.

- **11 Feb 2008:** Four inches of snow fell the evening of the 11th. 1/4 inch of ice early on the 12th glazed roads and brought about minor tree damage. Tree branches falling on power lines bought about a power outage to 4000 residents in the Louisville metropolitan area. Snow developed during the late afternoon on February 11th and continued until late evening. A swath of 3 to 4 inch accumulations fell across Hancock...Northern Breckenridge...Meade and Jefferson counties eastward along interstate 64 through the northern Bluegrass region. Freezing rain later developed across northern Kentucky during the pre-dawn hours on February 12th. Ice accumulations ranging from 1/4 of an inch to just under 1/2 of an inch were common until temperatures rose above freezing by late morning. Ice accumulations brought minor tree damage. The snow and freezing rain lead to numerous school and activity cancellations.
- **07 Mar 2008**: A snowstorm developed during the early morning hours Friday March 7th. Snow and some sleet fell intermittently over the next 28 hours. Snowfall totals were highest along the Ohio River, where accumulations varied from 10 to 12 inches. Farther south...snow started later in the day and accumulations were lower. Snow totals varied widely across the Bluegrass region, ranging from 8 inches in Frankfort to less than 4 inches south and east of Lexington. Sleet with occasional thunder fell across the eastern Bluegrass region late on the 7th...with 1 to 2 inches of sleet accumulating. Across south central Kentucky, snowfall ranged from over 8 inches north of Bowling green to just under 4 inches along the Kentucky-Tennessee border.
- **23 Dec 2008**: Slick roads due to light freezing rain lead to several injury-causing accidents and one fatality in the Louisville metropolitan area. The fatality occurred when a driver lost control of his vehicle and in eastern Louisville Metro. Another accident on the Gene Snyder Expressway injured two emergency workers who were providing aid to a driver hurt in an earlier crash. The three were taken to University Hospital with injuries that did not appear to be life-threatening. Emergency workers in Louisville responded to as many as 40 calls about accidents between 2 and 5 p.m. due to the icy conditions. Light freezing rain developed during the afternoon of December 23rd. Ice accumulation on roads across the northern portions of Kentucky lead to numerous traffic accidents and several fatalities.
- **26 – 28 January 2009** Historic Ice Storm on January 26, 2009 the storm began with snow which changed to freezing rain. Up to 6 inches of snow accumulated. Freezing rain continued over southern Kentucky. On Tuesday the 27th, precipitation changed to freezing rain over southern Indiana and northern Kentucky and to rain over southern Kentucky. Ice over an inch thick was reported in many locations from the freezing rain. Tuesday night freezing rain and sleet continued over southern Indiana, freezing rain transitioned to rain over northern Kentucky, and rain, occasionally heavy, continued over southern Kentucky. Minor river flooding developed in some spots by Wednesday from the steady rain. On the morning of Wednesday, January 28, precipitation changed over to snow from northwest to southeast across the area. About 3 to 4 inches of additional snow accumulation piled up in the north, with less to the south.

This was followed on February 3-5 with 20 mph wind gusts and subzero temperatures. By storm's end, there was a snow accumulation 2 to 10 inches and statewide power outages of more than 769,000. In Louisville Metro there were power outages for 404,000 people.

Governor Steve Beshear called the storm the 'Worst natural disaster in the history of Kentucky'. On January 29, 2009, President Obama announced an Emergency Declaration for Kentucky. In total, 101 out of 120 counties were declared a state of emergency and the President issued a Presidential Disaster Declaration on February 5 (DR 1818).

KyEM and FEMA estimated damage at more than $214 million. Kentucky issued the first ever call-up of Kentucky National Guard with 4,100 personnel/troops. The storm caused Kentucky's worst death toll with 36 storm-related deaths. A Partnership between KyEM and USACE resulted in the largest emergency generator placement of 160.

The affect on the power system surpassed all aspects of the Ike windstorm just five months earlier. The storm caused Kentucky's largest power outage on record, with 609,000 homes and businesses without power across the state. Property damage was widespread, with the damage due to falling trees, large tree limbs, and power lines weighed down by ice.

In the Louisville metropolitan area, 205,000 lost power and it took up to 10 days to get the power restored. Area school systems were closed for an entire week. Several emergency shelters were set up across the affected region. In Louisville's local school system, 69 schools lost power.

Following is the summary of Project Worksheets submitted due to DR 1818 – Ice Storm

Total Eligible Applicants – 66, Total Projects (PWs) 178

Category A - $5,225,398.20 /PWs = 62

Category B - $3,135,102.32 /PWs = 81

Category C - $51,751.00 /PWs = 2

Category D - $0 /PWs = 0

Category E - $42,324.20 /PWs = 21

Category F - $18,844.38 /PWs = 2

Category G - $16,324.57 /PWs = 43

Total Project Amount -$8,489,744.67

- **07 Jan 2010**: Three to four inches of snow fell countywide. Officially, 3 inches were measured by observers at Standiford Airport in Louisville. The local newspaper reported very slick roads and numerous traffic accidents. An upper level trough and a weak surface low moved across central Indiana during the day. Snow began near dawn and continued on an intermittent basis through late afternoon. Snow accumulations ranged from 3 to 4 inches across the northern Bluegrass Region and areas adjacent to the Ohio River, to around 1 inch near the Tennessee border. Precipitation remained all snow despite the northerly track of the surface low and light southerly winds. Due to antecedent cold temperatures, snow accumulated readily on roads and bridges, causing many accidents and travel problems.
- **29 Jan 2010**: Officially, 3.6 inches of snow fell at the Louisville International Airport. Four and one half inches of snow fell at the NWS forecast office. Traffic was severely hampered early Saturday morning. An upper level disturbance moved east from the southern plains through the Tennessee Valley late on a Friday night. This storm spread a broad swath of heavy snow extending from Oklahoma eastward across the Tennessee Valley and across the southern Appalachians through the Mid-Atlantic States. Snow slowly moved northeast into south central Kentucky by mid-afternoon Friday, January 29th. Light to moderate snow continued across central Kentucky before ending shortly after dawn on Saturday. Due to antecedent dry air, snow did not develop across north central Kentucky and the Bluegrass Region until late Friday evening. Four to 8 inches of snow fell across the southern tier of counties adjacent to Tennessee. This amount of snow had not been seen in this area for several years. Farther north, 4 to 6 inches of snow fell across central Kentucky along and south of a line from Louisville through Lexington. Other locations along the Ohio River northeast of Louisville and across the northern Bluegrass received 1 to 4 inches.
- **08 Feb 2010**: Just over 6 inches of snow fell at Standiford Field (Louisville International Airport) in Louisville. 6.3 inches was measured at the National Weather Service Forecast Office. An inverted trough moving across Tennessee combined with an upper low sliding south across the upper Midwest brought a mixture of heavy snow, sleet and rain across central Kentucky Tuesday morning February 9th. Snow began during the evening hours across south central Kentucky and moved north of Interstate 64 by midnight. By the early morning hours, snow had turned to sleet and rain south and east of a line from Breckinridge County through Henry County. Along the Ohio River, banded precipitation brought intermittent bursts of heavy snow around 8 to 9 am. The heaviest snow totals fell along the Ohio River, where 4 to 7 inches of accumulation were common. Sleet and rain limited snowfall amounts to 1 to 3 inches across south central Kentucky and the Bluegrass Region.

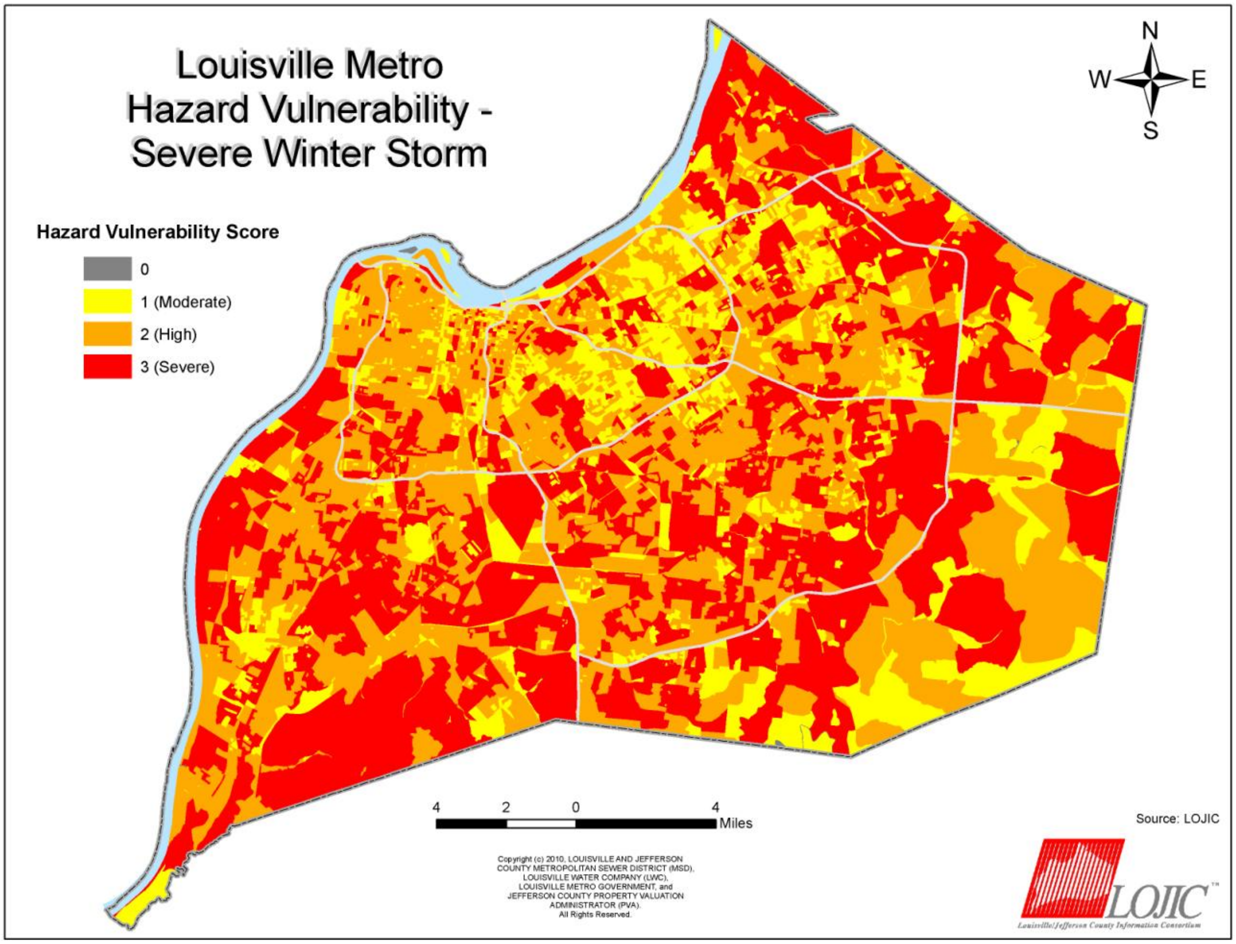
3.13.1.1 Assessing Vulnerability Overview: Severe Winter Storm

Severe Winter Storm Vulnerability Score = Exposure Score X Risk Score

The Severe Winter Storm Vulnerability Score is currently difficult to calculate. Currently Louisville Metro has no real spatial data that can be calculated to determine vulnerable areas to Severe Winter Storm. Severe Winter Storm is the type of hazard that typically affects a county the size of Louisville Metro equally. With that being said it was determined to use the Exposure

Score map to display the Severe Winter Storm Vulnerability Score based on the assumption that the entire county is equally vulnerable to Severe Winter Storm.

The Exposure Score does provide a visual display of areas that could be harder hit by Severe Winter Storm based on the exposure that is within each census block.



3.13.1.2 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: Severe Winter Storm

Identifying structures and estimating potential losses for Severe Winter Storm is very difficult at this time. Without any current spatial data that truly identifies Severe Winter Storm hazard boundaries it is assumed that the entire county has equal vulnerability and the potential to be damaged from Severe Winter Storm.

The total number of structures in Louisville is 263,146 with a replacement value of $38,017,288,909.

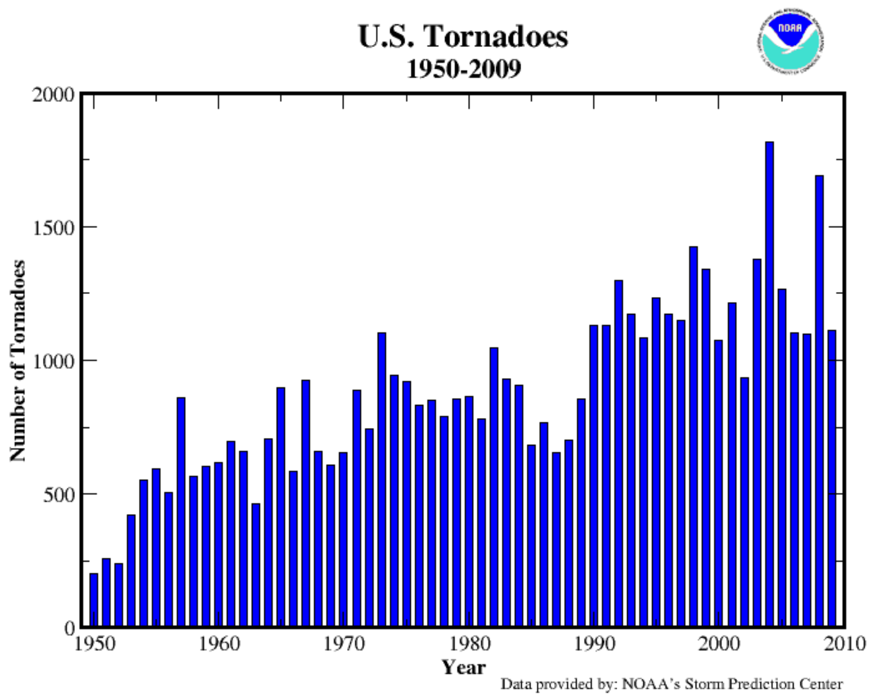
3.14 Tornado

Description: A tornado is a violent windstorm characterized by a twisting, funnel-shaped cloud extending to the ground. It is spawned by a thunderstorm (or sometimes as a result of a hurricane) and produced when cool air overrides a layer of warm air, forcing the warm air to rise rapidly.

In the U. S.

On April 3, 1974, 148 tornadoes in 13 states killed 315 people and is the largest recorded tornadic event in history.

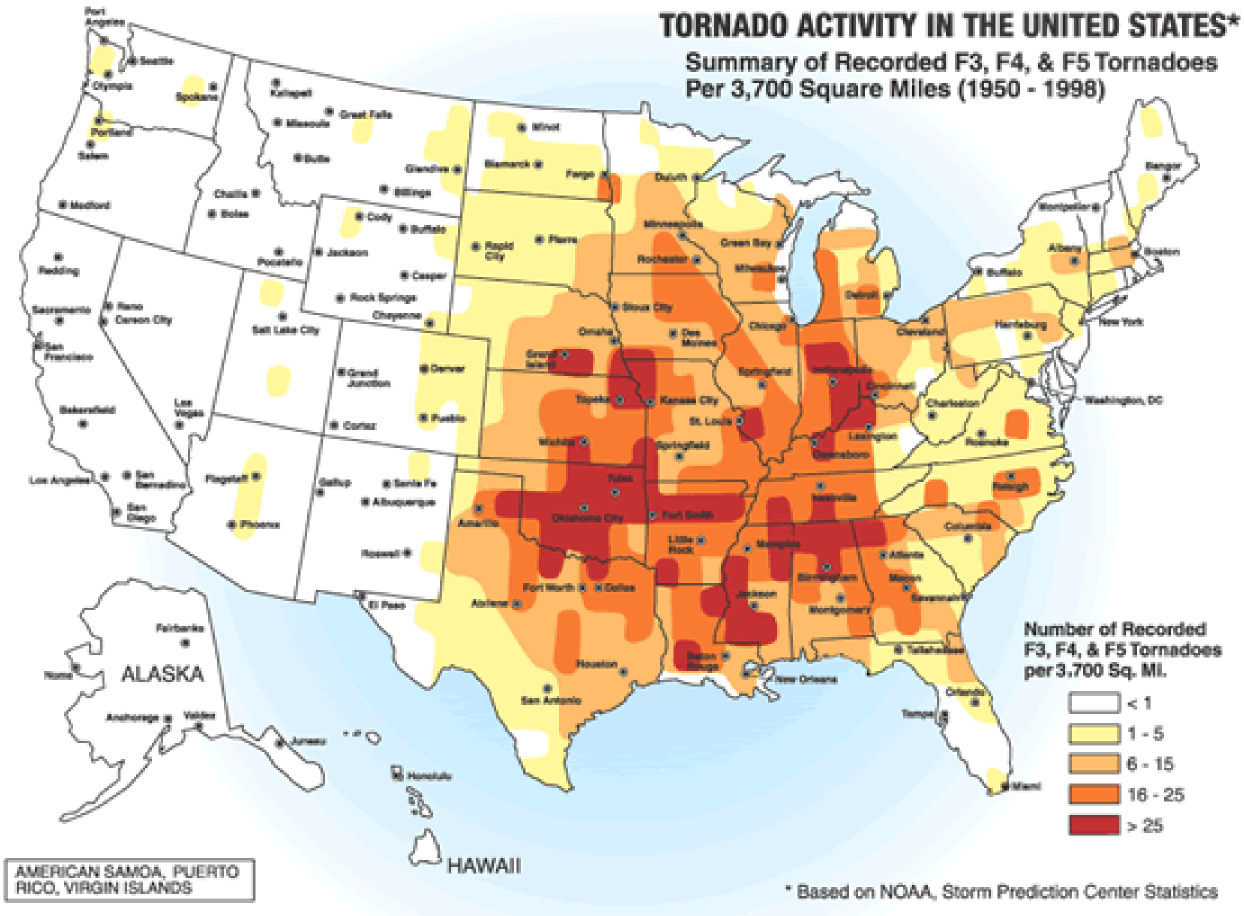
The damage from a tornado is a result of the high wind velocity and wind-blown debris with paths that can be in excess of one mile wide and fifty miles long. Tornado season is generally March through August, although tornadoes can occur at any time of year. They tend to occur in the afternoons and evenings; over 80 percent of all tornadoes strike between noon and midnight.



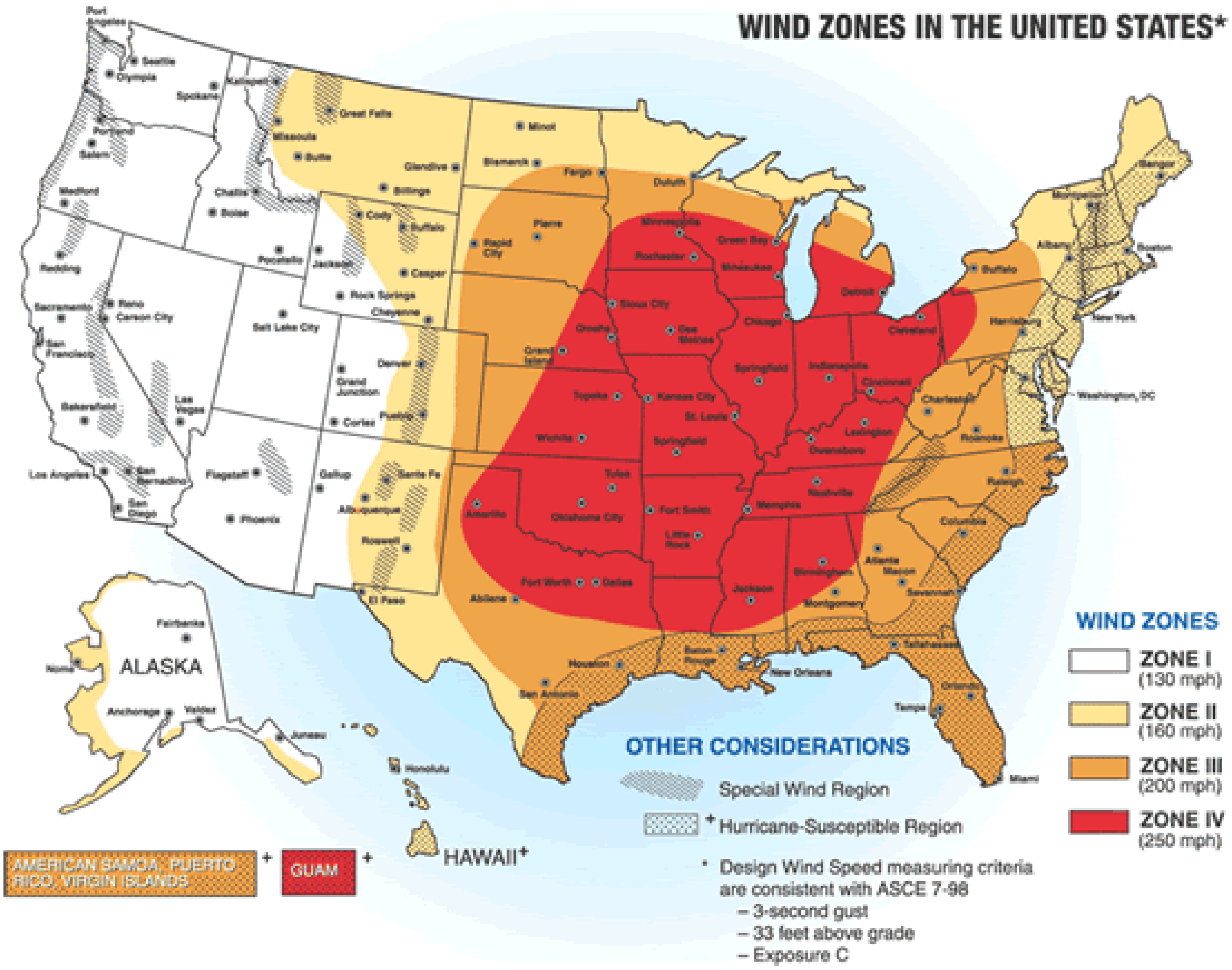
Most tornadoes are just a few dozen yards wide and touch down only briefly, but highly destructive tornadoes may carve out a path over a mile wide and several miles long. The destruction caused by tornadoes may range from light to catastrophic depending on the intensity, size, and duration of the storm. Effects of tornadoes may include crop and property damage, power outages, environmental degradation, injury, and death. Tornadoes are known to blow off roofs, move cars and tractor-trailers, and demolish homes.

Typically, tornadoes are localized in impact and cause the greatest damages to structures of light construction, such as residential homes. A tornado can move as fast as 125 mph with internal winds speeds exceeding 300 mph.

The following maps below illustrate the predictability of tornadic and wind zone activity according to NOAA and FEMA.



http://www.fema.gov/plan/prevent/saferoom/tsfs02_torn_activity.shtm



http://www.fema.gov/plan/prevent/saferoom/tsfs02_wind_zones.shtm

Tornado Types

The magnitude of a tornado is categorized by the damage pattern (i.e. path) and wind velocity, according to the Fujita-Pearson Tornado Measurement Scale. This scale is the only widely used rating method with the aim to validate classification by relating the degree of damage to the intensity of the wind.

Enhanced F Scale for Tornado Damage

Following is an update to the Original F-Scale by a team of meteorologists and wind engineers, to be implemented 1 February 2007.

FUJITA SCALE			DERIVED EF SCALE		OPERATIONAL EF SCALE	
F Number	Fastest 1/4-mile (mph)	3 Second Gust (mph)	EF Number	3 Second Gust (mph)	EF Number	3 Second Gust (mph)
0	40-72	45-78	0	65-85	0	65-85
1	73-112	79-117	1	86-109	1	86-110
2	113-157	118-161	2	110-137	2	111-135
3	158-207	162-209	3	138-167	3	136-165
4	208-260	210-261	4	168-199	4	166-200
5	261-318	262-317	5	200-234	5	Over 200

***** IMPORTANT NOTE ABOUT ENHANCED F-SCALE WINDS:** *The Enhanced F-scale still is a set of wind estimates (not measurements) based on damage.* Its uses three-second gusts estimated at the point of damage based on a judgment of 8 levels of damage to the 28 indicators listed below. These estimates vary with height and exposure. **Important**: The 3 second gust is not the same wind as in standard surface observations. Standard measurements are taken by weather stations in open exposures, using a directly measured, and "one minute mile" speed.

Enhanced F Scale Damage Indicators

NUMBER	DAMAGE INDICATOR	ABBREVIATION
1	Small barns, farm outbuildings	SBO
2	One- or two-family residences	FR12
3	Single-wide mobile home (MHSW)	MHSW
4	Double-wide mobile home	MHDW
5	Apt, condo, townhouse (3 stories or less)	ACT
6	Motel	M
7	Masonry apt. or motel	MAM
8	Small retail bldg. (fast food)	SRB
9	Small professional (doctor office, branch bank)	SPB
10	Strip mall	SM
11	Large shopping mall	LSM
12	Large, isolated ("big box") retail bldg.	LIRB
13	Automobile showroom	ASR
14	Automotive service building	ASB
15	School - 1-story elementary (interior or exterior halls)	ES
16	School - jr. or sr. high school	JHSH
17	Low-rise (1-4 story) bldg.	LRB
18	Mid-rise (5-20 story) bldg.	MRB
19	High-rise (over 20 stories)	HRB
20	Institutional bldg. (hospital, govt. or university)	IB

NUMBER	DAMAGE INDICATOR	ABBREVIATION
21	Metal building system	MBS
22	Service station canopy	SSC
23	Warehouse (tilt-up walls or heavy timber)	WHB
24	Transmission line tower	TLT
25	Free-standing tower	FST
26	Free standing pole (light, flag, luminary)	FSP
27	Tree - hardwood	TH
28	Tree - softwood	TS

Tornado Facts

- Worldwide, annually about 1,000 tornadoes are generated by severe thunderstorms.
- Earthquake-induced fires and wildfires may also produce tornadoes.
- Powerful tornadoes have lifted and moved objects weighing more than 300 tons a distance of thirty feet and have tossed homes greater than 300 feet way from their foundations.
- The path of a single tornado can be dozens of miles long, but tornadoes rarely last longer than 30 minutes.

3.14.1 Tornado Profile

SUMMARY OF TORNADO RISK FACTORS

Period of occurrence:	Year-round, primarily during March through August. The month of May normally experiencing the greatest number of tornadoes.
Number of Events to-date 1960-2010:	14
Probability of event(s):	0.28
Warning time:	Minutes to hours. Over 80 % of all tornadoes strike between noon and midnight.
Potential Impact(s):	Utility damage and outages, infrastructure damage (transportation and communication systems), structural damage, and damaged or destroyed critical facilities. Impacts human life, health, and public safety.
Past Damages	$15,000,384

Background: The occurrence of a Kentucky tornado is predictable because a tornado touches down somewhere in Kentucky every year. Kentucky is located in the most severe wind zone (ZONE IV 250 mph) in the country. This signifies that most of the state is highly vulnerable to tornadic weather. Tornadoes are somewhat common throughout Kentucky and have occurred in every month of the year. Conversely, the occurrence of a tornado is highly unpredictable because it is impossible to forecast the exact time and location that it will touch down and the path that it will take.

Most tornadoes occur between March and July, with the month of May normally experiencing the greatest number of tornadoes. The strongest tornadoes, which usually result in the highest number of deaths and greatest destruction of property, occur between April and June. Most deaths occur in April, which is considered the beginning of the tornado season.

In Kentucky

Tornadoes may occur in any part of the state at any time of year; however, the western and central portions have experienced greater frequency.

The months of March, April and May seem to have the most severe tornadoes.

Since 1950, Kentucky has averaged 8.4 tornadoes per year. There were 19 tornadoes reported in 1973; in 1974 there were a total of 34. (LMEOP)

Tornado Potential Impact

Due to the destructive nature of tornadoes and wind, these events impact human life, health, and public safety. Community-wide impacts include: utility damage and outages, infrastructure damage (transportation and communication systems), structural damage, and damaged or destroyed critical facilities. Tornadoes can also cause severe transportation problems and make travel extremely dangerous.

Louisville Metro Tornado History

In Louisville Metro tornadoes have occurred in 1890, 1917, 1925, 1928, 1964, 1969, 1974, 2006, and 2008. Injuries, damages, and fatalities attributed to tornadoes have also been on the increase in recent years. In 1971 there were nine deaths and some 130 injuries from tornadoes. In 1974 there were 76 tornado fatalities and approximately 1,000 personal injuries from the exceptionally high number of tornadoes that affected the state that year. (LMEOP). One tornado event has been Presidentially declared for Louisville Metro, as shown in this table.

Tornadoes NWS Reports for Louisville Metro

At least **23 tornadoes** since 1830.

Strongest: There have been **five F4's.**

March 27, 1890 76 fatalities

April 3, 1974 2 fatalities

Since 1987 29 Tornados

Most Warnings in one day 5 on May 30, 2004

DR #	Declaration Date	Disaster Type	Deaths	Injuries	Total Declared Counties in Kentucky
420	4/4/1974	Tornado	3	226	34

Following is a NCDC list of four tornados in the Louisville Metro area between 2005 – 2010.

Location	Date	Time	Type	Mag	Death	Injuries	Property Damage
1. Louisville	04/22/2005	05:47 PM	Tornado	F0	0	0	100K
2. St Dennis	01/02/2006	03:22 PM	Tornado	F1	0	0	250K
3. Highlands	10/18/2007	18:10 PM	Tornado	F0	0	0	3K
4. Louisville	01/29/2008	20:00 PM	Tornado	F1	0	0	3.0M
				TOTALS	**0**	**0**	**$3,353,000**

- **22 April 2005:** The tornado first touched down near the intersection of Campbell and Market Streets, where the roof on a business was destroyed, and a telephone pole was snapped. An empty trailer was flipped over near this location. The Stockyard Farm Supply Company on South Johnson Street sustained roof damage.
- **2 January 2006**: A tornado touched down at the corner of Bramers and Campground Road in western Louisville Metro. Many homes along the damage path had roof damage. Numerous trees and power lines

were downed; one tree was blown on to a house. The local Moose Lodge building had significant damage.

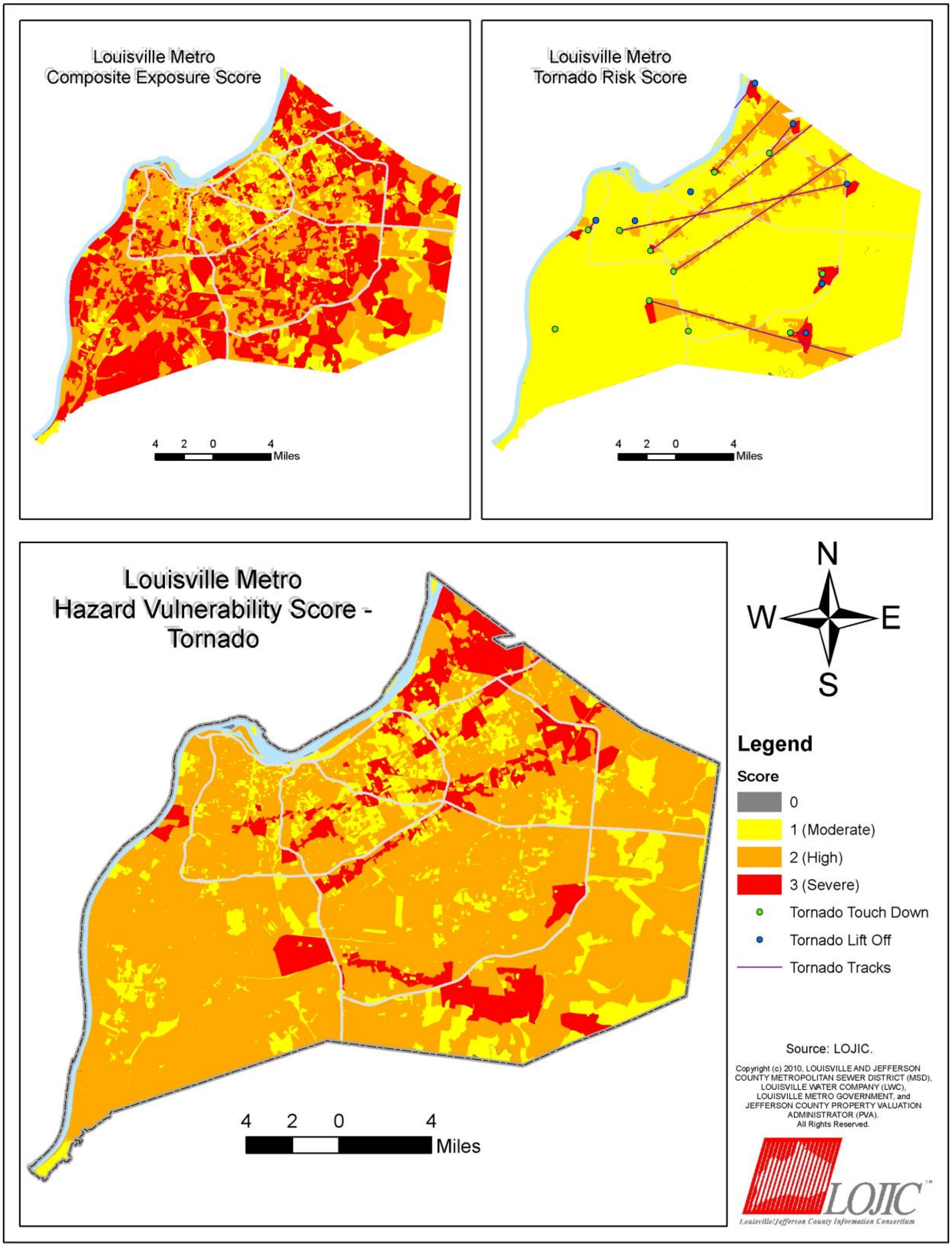
- **18 October 2007**: The EF-0 tornado touched down briefly at a grocery store at 2200 Brownsboro Road. A cold front with strong upper level support collided with a very moist air mass over the lower Ohio Valley. The result was a widespread outbreak of severe thunderstorms, and six confirmed tornadoes. The storms produced property damage, downed trees and power lines, and large hail.
- **29 January 2008**: A fast moving EF-1 tornado briefly touched down four times in the Louisville Metro area as a squall line crossed the city. The tornado was on the ground for approximately 1.5 miles over the course of its 16-mile long track. The first touchdown was in and industrial area just off Millers Lane west of the Dixie Highway. The tornado stayed on the ground for one mile before lifting, heavily damaging a church on Dixie Highway, as well as uprooting and snapping several trees and damaging numerous homes. The tornado then dipped again on the west side of the University of Louisville campus, breaking out many windows and damaging several vehicles. The next touchdown in St. Matthews near the intersection of Shelbyville Road and Interstate 264, caused extensive damage to many businesses and private properties. The fourth and final touchdown was in Anchorage where trees were damaged, blown over, and uprooted, roofs were damaged, and a large outbuilding at a training school was destroyed. A large number of locations had 60 to as much as 100 mph winds, causing extensive property damage. There were also a few small tornado spin-ups.

3.14.1.1 Assessing Vulnerability Overview: Tornado

Tornado Vulnerability Score = Exposure Score X Risk Score

Assessing vulnerability by census block was determined through creating the Tornado Risk Score using the Tornado Occurrence Rank. The Tornado Occurrence Rank was calculated using GIS point and tracks data provided by the NOAA Storm Prediction Center's SVRGIS datasets. These datasets geo-locate Tornado touch downs, lift offs and tracks throughout the United States. The Project Staff took the national dataset and clipped it to Louisville Metro using a spatial analysis clip tool within GIS. The Tornado Occurrence Rank was then calculated by counting the number of occurrences within each census block and then ranked 0 to 3 (0 = No data, 1 = Moderate, 2 = High, and 3 = Severe). This model displayed the areas of high probability based on past events occurring in a particular location.

The Tornado Vulnerability Score was calculated for each census block by multiplying the census block's Exposure Score by its Tornado Risk Score.


Louisville Metro
Composite Exposure Score
4 2 0 4
Miles
Louisville Metro
Tornado Risk Score
4 2 0 4
Miles
Louisville Metro
Hazard Vulnerability Score -
Tornado
4 2 0 4
Miles
N
W
E
S
Legend
Score
0
1 (Moderate)
2 (High)
3 (Severe)
Tornado Touch Down
Tornado Lift Off
Tornado Tracks
Source: LOJIC.
Copyright (c) 2010, LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT (MSD), LOUISVILLE WATER COMPANY (LWC), LOUISVILLE METRO GOVERNMENT, and JEFFERSON COUNTY PROPERTY VALUATION ADMINISTRATOR (PVA). All Rights Reserved.
LOJIC
Louisville/Jefferson County Information Consortium

3.14.1.2 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: Tornado

In order to determine structures that are vulnerable and estimated to be damaged during a Tornado event the Project Staff used the Hazard Boundary Overlay methodology. The Hazard Boundary used as the overlay was the Severe (3) census blocks. These Severe (3) census blocks identify areas of high probability for a Tornado event, thus was used to showcase areas of severe risk in this model.

The following table describes the total number of structures identified within the hazard boundary and the replacement cost of those structures. This model estimates complete damage of each structure located within the Hazard Boundary.

TORNADO	STRUCTURES
COMMERCIAL	1,112
INDUSTRIAL	461
RESIDENTIAL	14,609
OTHER	1,177
TOTAL BUILDINGS	**17,359**
ESTIMATED LOSS	**$4,277,203,867**

3.15 Wildfire

Description: A wildfire is an unplanned fire, which includes grass fires, forest fires, and scrub fires either man-made or natural in origin. There are three different classes of wildland fires. A *wildfire* is an uncontrolled burning of grasslands, brush, or woodlands.

Humans, either through negligence, accident, or intentional arson, have caused approximately 90% of all wildfires in the last decade. Accidental and negligent acts include unattended campfires, sparks, burning debris, and irresponsibly discarded cigarettes. The remaining 10% of fires are mostly caused by lightning, but may also be caused by other acts of nature such as volcanic eruptions or earthquakes.

> **In the U. S.**
>
> Each year in the U.S. fire injures 23,000 and kills 4,000, making America among the highest in per capita death rate due to fire in the industrialized world.

Wildfires become significant threats to life and property along what is known as the “wildland/urban interface”. The wildland/urban interface is defined as the area where structures and other human development meet or intermingle with undeveloped wild land or vegetative fuels.

The potential for wildfire depends upon surface fuel characteristics, weather conditions, recent climate conditions, topography, drought, and fire behavior. Weather is the most variable and impacts fire behavior most often. The main weather factors that have an effect on fire behavior are temperature, wind, and relative humidity. Wind increases the rate and the direction of fire spread. Relative humidity and temperature mainly affect fuel moisture. Changes in the weather, such as an approaching cold front, can greatly affect wind speed and direction, temperature and relative humidity, which in turn can greatly affect wildfire behavior. It is critical that firefighters understand the relationship of weather to fire behavior and keep abreast of any weather changes.

Fuels are anything that fire can and will burn, and are the combustible materials that sustain a wildfire. Typically, this is the most prevalent vegetation in a given area. Weather is one of the most significant factors in determining the severity of wildfires. The intensity of fires and the rate with which they spread is directly rated to the wind speed, temperature, and relative humidity. Climatic conditions such as long-term Drought Severe Winter Storm also play a major role in the number and intensity of wildfires, and topography is important because the slope and shape of the terrain can change the rate of speed at which fire travels.

Wildfire Types

- *Surface fires* are the most common type and burn along the floor of a forest, moving slowly and killing or damaging trees.
- *Ground fires* are usually started by lightning and burn on or below the forest floor.
- *Crown fires* spread rapidly by wind and move quickly by jumping along the tops of trees.
- *Spotting* can be produced by crown fires as well as wind and topography conditions. Large burning embers are thrown ahead of the main fire. Once spotting begins, the fire will be very difficult to control.

Wildfire Fuel Categories

- *Light fuels* such as shrubs, grasses, leaves, and pine needles (any fuel having a diameter of one-half inch or less) burn rapidly and are quickly ignited because they are surrounded by plenty of oxygen. Fires in light fuels spread rapidly but burn out quickly, are easily extinguished, and fuel moisture changes more rapidly than in heavier fuels.
- *Heavy fuels* such as limbs, logs, and tree trunks (any fuel one-half inch or larger in diameter) warm more slowly than light fuels, and the interiors are exposed to oxygen only after the outer portion is burned.
- *Uniform fuels* include all of the fuels distributed continuously over an area. Areas containing a network of fuels that connect with each other to provide a continuous path for a fire to spread are included in this category.
- *Patchy fuels* include all fuels distributed unevenly over an area, or as areas of fuel with definite breaks or barriers present, such as patches of rock outcroppings, bare ground, swamps, or areas where the dominant type of fuel is much less combustible.
- *Ground fuels* are all of the combustible materials lying beneath the surface including tree roots, rotten buried logs, and other organic material.
- *Surface fuels* are all of the combustible materials lying on or immediately above the ground, including needles or leaves, duff, grass, small deadwood, downed logs, stumps, large limbs, and low shrubs.
- *Aerial fuels* are all of the green and dead materials located in the upper canopy, including tree branches and crowns, snags, hanging moss, and tall shrubs.

Fuel Types

- *Grass*. Found in most areas, but grass is more dominant as a fuel in desert and range areas where other types of fuel are less prevalent. It can become prevalent in the years after a fire in formerly timbered areas.
- *Shrub* (brush). Shrub is found throughout most areas of the U.S. Some examples of highly flammable shrub fuels are the palmetto/ gallberry in the Southeast, sagebrush in the Great Basin, and chaparral in the Southwest.
- *Timber litter*. This type of fuel is most dominant in mountainous topography, especially in the Northwest.
- *Logging slash*. This fuel is found throughout the country. It is the debris left after logging, pruning, thinning, or shrub-cutting operations. It may include logs, chunks, bark, branches, stumps, and broken understory trees or shrubs.

Fuel Characteristics

Fuel moisture is the amount of water in a fuel. This measurement is expressed as a percentage. The higher the percentage, the greater the content of moisture within the fuel. How well a fuel will ignite and burn is dependent, largely, on its moisture content. Dry fuels will ignite and burn much more easily than the same fuels when they are wet (contain a high moisture content). As a fuel's moisture content increases, the amount of heat required to ignite and burn that fuel also increases.

Light fuels take on and lose moisture faster than heavier fuels. Wet fuels have high moisture content because of exposure to precipitation or high relative humidity, while dry fuels have low moisture content because of prolonged exposure to sunshine, dry winds, Severe Winter Storm, or low relative humidity.

Wildfire Facts

- Homeowners can do much to help save their homes from wildfires, such as constructing the roof and exterior structure of a dwelling with non- combustible or fire resistant materials such as tile, slate, sheet iron, aluminum, brick or stone.
- One of the worst wildfire seasons, in terms of number of acres burned was 2000 when wildfires burned 8.4 million acres. Scientific analysis of the 2000 fire season revealed that the vast majority of burned acres were located in previously logged and roaded areas. The worst fire seasons were in 1963, 1988, and 2004.
- Drought causes and increased incidence in wildland and residential fires

3.15.1 Wildfire Profile

SUMMARY OF WILDFIRE RISK FACTORS

Period of occurrence:	Year-Round, primarily Summer
Number of Events to-date 2000-2010	4
Probability of event(s):	0.40 Chances of occurrence increase with drought or earthquake.
Warning time:	None, unless related to drought. Humans, through negligence, accident, or intentional arson, have caused approximately 90% of all wildfires in the last decade.
Potential Impact(s):	Impacts human life, health, and public safety. Loss of wildlife habitat, increased soil erosion, and degraded water quality. Utility damage and outages, infrastructure damage (transportation and communication systems), structural damage, damaged or destroyed critical facilities, and hazardous material releases.
Past Damages:	No data

Background

Wildland fires have been occurring in Kentucky for thousands of years. Native Americans used fire to clear land for wildlife. Settlers moving into the state adopted the Native American land-clearing techniques, including the use of fire.

The Cumberland Plateau and the Appalachians in the eastern part of the state account for 50 percent of the state's forest cover, with 25 contiguous counties having a forest cover percentage of greater than 75 percent.

Oak-hickory is the dominant forest cover and covers 8.4 million acres, or 72 percent of the state's forested land. Oak-pine forests make up 9 percent, maple-beech-birch and aspen-birch make up 7 percent, oak-gum-cypress and elm-ash-cottonwood make up 6 percent, softwood makes up 5 percent, and non-stocked, 1 percent.

In Kentucky

Kentucky has more than 11.9 million acres of forestland. Eighty-nine percent of the forestland in Kentucky is privately owned.

Since 1945, Kentucky has experienced over 126,000 wildfires which burned 5,003,952 acres statewide.

Private individuals own 78 percent of the timberland in Kentucky. Nine percent is public land administered by local, State, or federal agencies. Slightly more than one-half of the public timberland is managed by the U.S. Forest Service. Forest industry owns 2 percent of the timberland and other corporations account for the remaining 11 percent. The Division of Forestry owns and manages eight state forests - Tygarts, Green River, Pennyrile, Kentucky Ridge, Kentenia, Marrowbone, Knobs, and Rolleigh Peterson with a combined total of 39,401 acres.

The Division of Forestry is responsible for fighting wildland fires on private lands and enforcing forest fire hazard seasons and other outdoor burning regulations. The Division fights over 1,800 wildland fires annually. These fires burn more than 50,000 acres per year. The leading cause of forest fires in Kentucky is arson. Arson is the act of intentionally and/or maliciously setting a fire. Wildland arson is a serious crime that hurts all Kentuckians.

Kentucky's forest protection laws include penalties for intentionally setting a fire on land owned by another (KRS 149.380). The penalties for violating KRS 149.380 include a fine of not less than $1,000 or more than $10,000, imprisonment for not more than five years, or both fine and imprisonment.

Kentucky Forest Fire Hazard Seasons

- Feb. 15 through April 30 and
- Oct. 1 through Dec. 15.

During this time, it is illegal to burn between the hours of 6 a.m. and 6 p.m. in or within 150 feet of any woodland or brushland.

Wildfire Potential Impact

Wildfire impacts human life, health, and public safety as well as a loss of wildlife habitat, increased soil erosion, and degraded water quality. Wildfire also can cause utility damage and outages, infrastructure damage (transportation and communication systems), structural damage, damaged or destroyed critical facilities, and hazardous material releases.

Because smoke from wildfires is a mixture of gases and fine particles from burning trees and other plant materials, it can irritate eyes and cause damage to respiratory systems causing shortness of breath, chest pain, headaches, asthma exacerbations, coughing, and death. For those with heart disease, rapid heartbeat and fatigue may be experienced more readily under smoky conditions.

Included in the destruction by fires are the leaf and other litter on the forest floor. This exposes the soil to erosive forces, allowing rainstorms to wear away the naked soil and wash silt and debris downhill, which will clog the streams and damage fertile farmlands in the valleys. Once the litter and humus (spongy layer of decaying matter) is destroyed, water flows more swiftly to the valleys and increases flood danger.

Other consequences of wildfires are the death of and loss of habitat for the forest’s wildlife. The heaviest wildlife lost is felt by game birds since they have ground nesting habits. Fish life also suffers because of the removal of stream shade and the loss of insect and plant food is destroyed by silt and lye from wood ashes washed down from burned hillsides.

Wildland fires are usually signaled by dense smoke that fills the area for miles around. The average forest fire kills most trees up to 3-4 inches in diameter, in the area burned. These trees represent approximately 20 years of growth. In the case of up-slope burning, under severe conditions, almost every tree is killed regardless of size or type. When the trees are burned and everything is killed, then the forest is slow to reestablish itself, because of the loss of these young seedlings, saplings, pole, and sawtimber trees.

Louisville Metro Wildfire History

According to wildfire data provided by the Kentucky Division of Forestry there have been four identified wildfires in Louisville Metro. These were small scale events on the following dates:

- 03 October 03, 01
- 27 February, 06
- 12 March, 10
- 12 October, 10

Local data shows that on October 12, 2010, a small campfire in the Pleasure Ridge Park area ignited a fire with 20- foot high flames and burned across three acres. It happened off of St. Andrews Church Rd., just across from Doss High School and very close to an apartment complex.

3.15.1.1 Assessing Vulnerability Overview: Wildfire

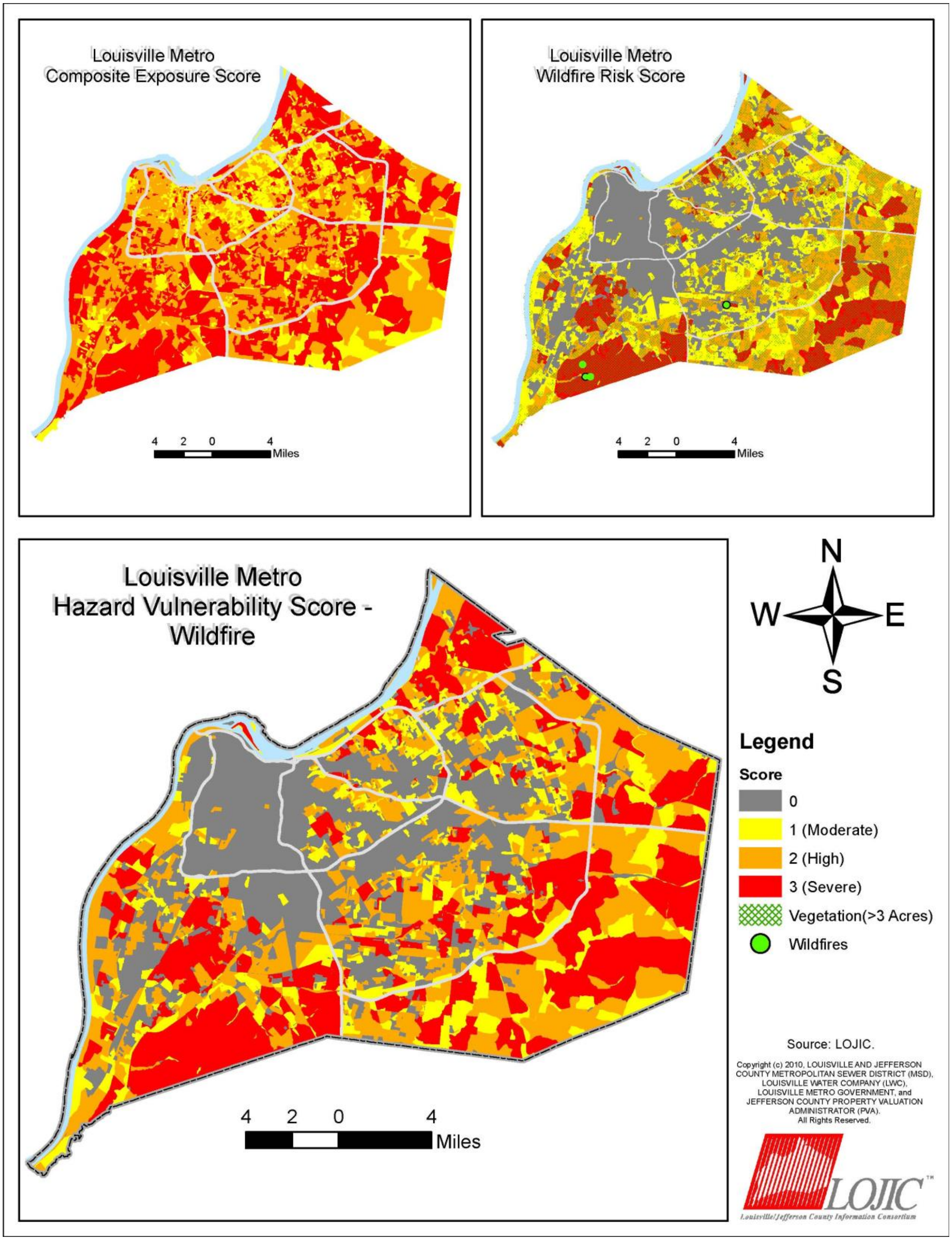
Wildfire Vulnerability Score = Exposure Score X Risk Score

Assessing vulnerability by census block was determined through creating the Wildfire Risk Score adding the Occurrence Rank and Area Affected Rank. The Occurrence Rank was determined by counting the number of Wildfire events located within each census block. The Wildfire locations were identified by the Kentucky Division of Forestry. The Occurrence Rank provided an understanding of where high concentrations of Wildfires are located within the community, thus producing areas of risk. The census blocks were then ranked 0 to 3 (0 = No data, 1 = Moderate, 2 = High, and 3 = Severe).

The Area Affected Rank was calculated by taking the percentage of the census block affected determined by identifying areas of Louisville metro having 3-acre or more tree cover/vegetation. The 3-acre or greater rule was discussed with Metro's local fire personnel and believed to be the best way to identify at risk areas.

The percentage of area affected by the 3-acre tree or greater vegetation areas was then calculated and ranked 0 to 3 (0 = No data, 1 = Moderate, 2 = High, and 3 = Severe). Next, the Wildfire Occurrence Rank and Area Affected Rank scores were added together to produce the Wildfire Risk Score.

The Wildfire Vulnerability Score was calculated for each census block by multiplying the census block's Exposure Score by its Wildfire Risk Score.


Louisville Metro
Composite Exposure Score
4 2 0 4
Miles
Louisville Metro
Wildfire Risk Score
4 2 0 4
Miles
Louisville Metro
Hazard Vulnerability Score -
Wildfire
4 2 0 4
Miles
N
W
E
S
Legend
Score
0
1 (Moderate)
2 (High)
3 (Severe)
Vegetation(>3 Acres)
Wildfires
Source: LOJIC.
Copyright (c) 2010, LOUISVILLE AND JEFFERSON COUNTY METROPOLITAN SEWER DISTRICT (MSD), LOUISVILLE WATER COMPANY (LWC), LOUISVILLE METRO GOVERNMENT, and JEFFERSON COUNTY PROPERTY VALUATION ADMINISTRATOR (PVA).
All Rights Reserved.
LOJIC
Louisville/Jefferson County Information Consortium

3.15.1.2 Assessing Vulnerability: Identifying Structures and Estimating Potential Losses: Wildfire

In order to determine structures that are vulnerable and estimated to be damaged during a Wildfire event the Project Staff used the Hazard Boundary Overlay methodology. The Hazard Boundary used as the overlay was the 3-acre tree/vegetation Wildfire map. This Wildfire potential map displays areas where there is a concentration of vegetation, thus displaying areas where potential losses from Wildfires could occur.

The following table describes the total number of structures identified within the hazard boundary and the replacement cost of those structures. This model estimates complete damage of each structure located within the Hazard Boundary.

WILDFIRE	STRUCTURES
COMMERCIAL	160
INDUSTRIAL	19
RESIDENTIAL	4,922
OTHER	258
TOTAL BUILDINGS	**5,359**
ESTIMATED LOSS	**$1,374,881,973**

3.16 Assessing Vulnerability: Analyzing Development Trends

An analysis of development trends provides a basis for making decisions on the type of mitigation approaches to consider, and the locations where these approaches can be implemented. This information can also be used to influence decisions regarding future development in hazard areas.

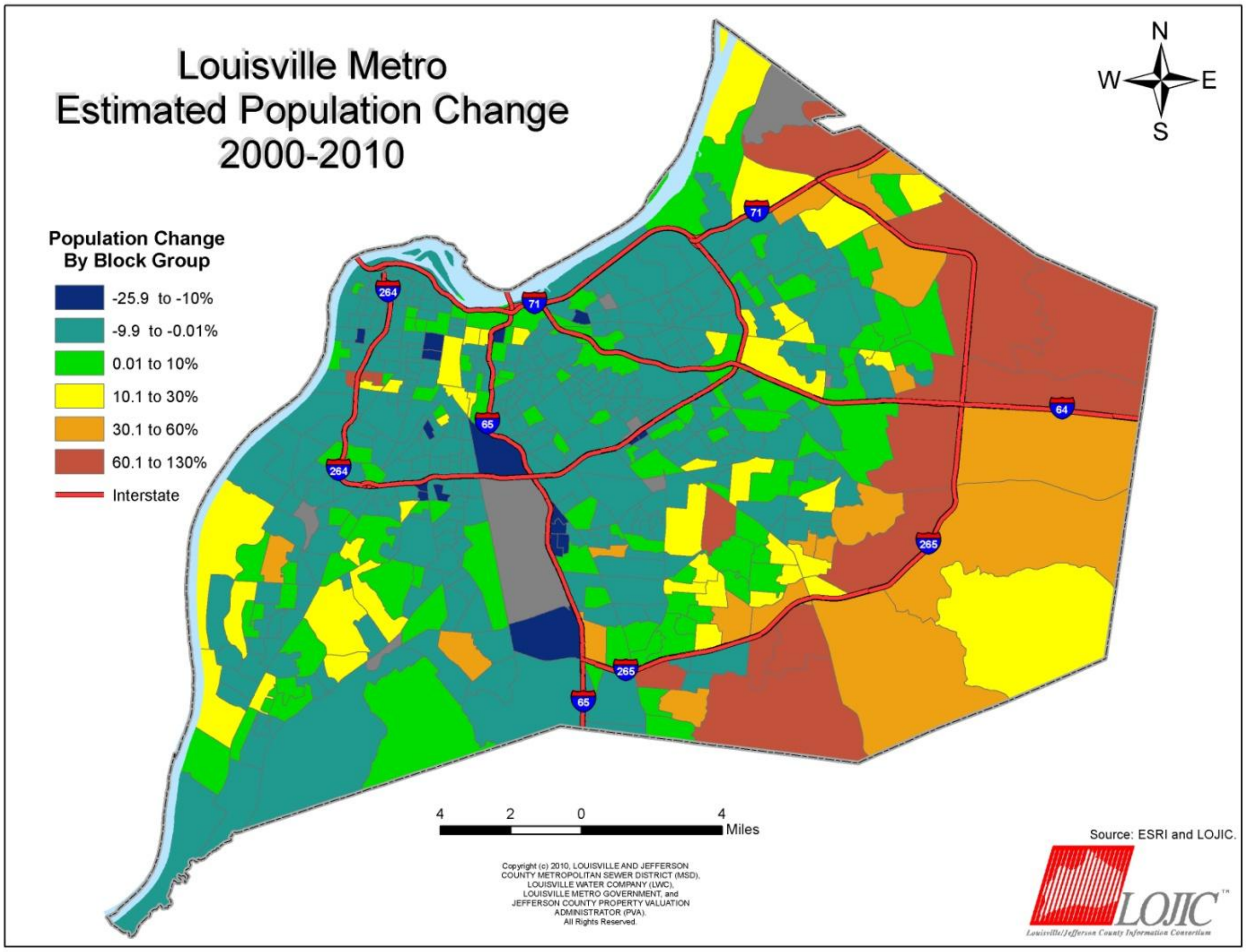
The Local Mitigation Plan *should* consider any or all of the following when analyzing development trends:

- Describe trends in terms of the amount of change over time and identify where the development is occurring
- Differentiate landuses of similar types that have distinctly different densities (for example, single-family homes, attached housing, and multifamily housing)
- Where the future land uses are likely to occur based on comprehensive plans, zoning, redevelopment plans, or proposed annexation areas
- The expected growth or redevelopment for some reasonable future timeframe (for example, 10 years)

There are several different methodologies in place that assess development trends. The following section describes the methodologies used for the Louisville Metro Multi-Hazards Mitigation Plan. Each of the models explained in this section depict different ways to capture development/population trends. Using each model can be an effective way to assess and analyze Louisville Metro development trends.

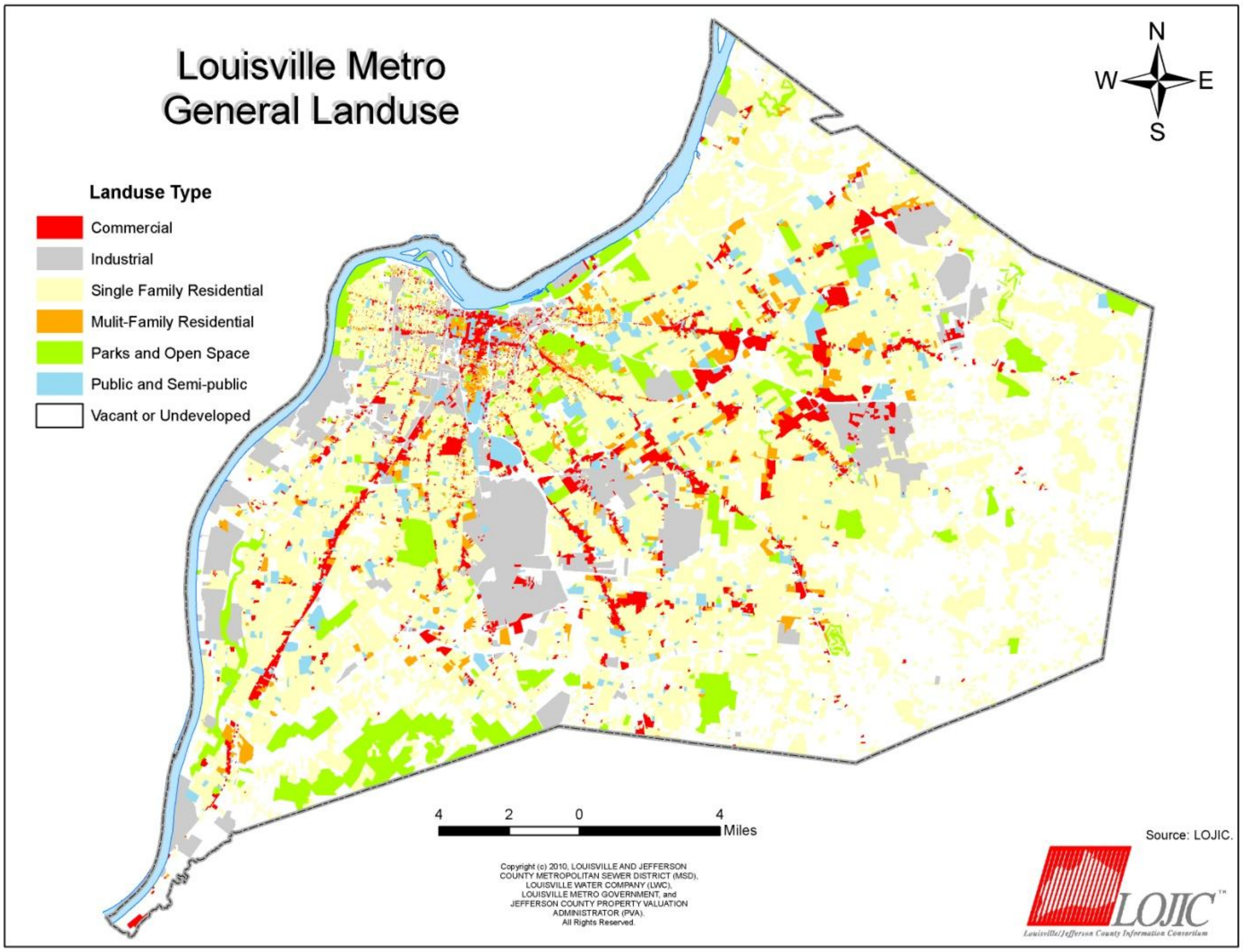
3.16.1 Population Trends

The most common methodology is to review population change data. This is a predictive methodology based on the estimated population change during a certain timeframe. The timeframe that was used for this model was years 2000-2010. This data shows population growth mainly in the eastern part of the city. The data was calculated using census tracts in order to overlay onto the *Hazard Vulnerability Score* maps giving the user the ability to depict areas of high risk and high growth based on population trends.



3.16.2 Landuse

Another model used for the Plan was to review the community's landuse maps. Using the existing Land Use map from Louisville's Cornerstone 2020 project helped depict where growth can occur based on comprehensive plans and zoning. It will be important for the community to overlay the *Hazard Vulnerability Score* and or the *Risk Score* data onto the landuse map when contemplating future land use changes.



3.16.3 Development Trends

In order to understand true Development Trends throughout the Louisville Metro planning area the Project Staff developed a new methodology. The model that was developed incorporated data variables that directly related to development in our community.

LOJIC along with Louisville Inspections, Permits and Licenses (IPL) track three specific variables that were used to analyze development trends. The data included the identification of new roads built from 2005-2010, the identification of new suburbs proposed using the recording of suburb record plats from 2005-2010, and the identification of Certificate of Occupancy Permits (Residential, Commercial and Industrial) granted from 2005-2010.

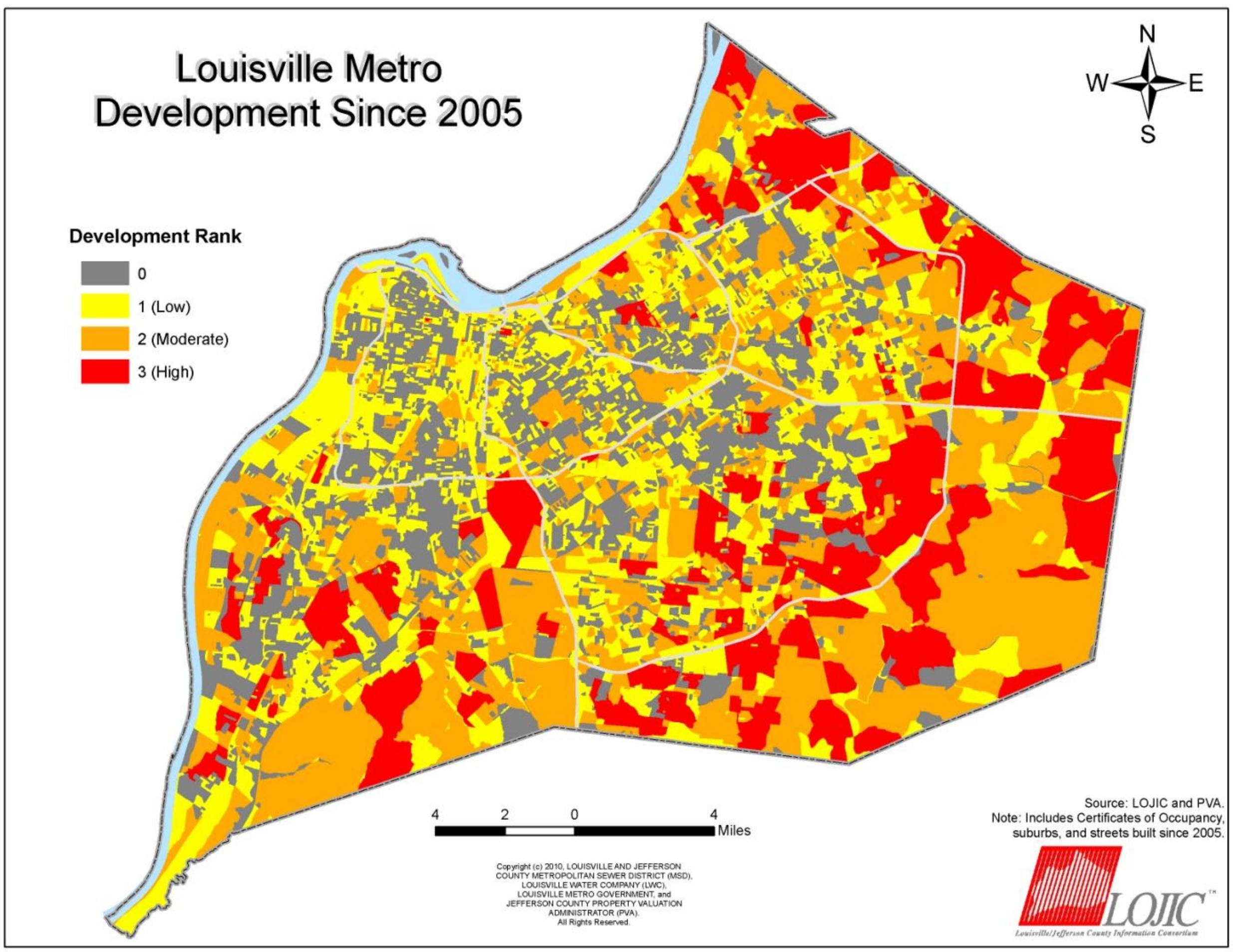
This data was geo-located using GIS analysis and incorporated into the Census Block planning areas. The model created was developed to mimic the models used in the *Hazard Vulnerability Score* methodology. Each data variable was aggregated to the census block it was located within.

For roads, the miles of roads was used as the unit of measure, proposed suburbs were measured using the percentage of the area the proposed suburbs covered (Area Affected Rank), and the number of Certificates for Occupancy were calculated by total number per census block (Occurrence Rank).

Each variable was calculated and ranked 0 to 3 (0 = No data, 1 = Moderate, 2 = High, and 3 = Severe), again to mimic the *Hazard Vulnerability Score* model.

This model provides a development trend model based on actual development data that has been assimilated over the last five years. The areas in red depict trends of high growth over the last five years. The design of the model was developed to match the *Hazard Vulnerability Score* model in order for users to overlay the two models and understand where high growth and high risks are located in correlation with each other.

Below is a map depicting growth and development in Louisville Metro since 2005.



3.17 Hazard Ranking and Risk Matrix

The hazard ranking was derived from reviewing the following quantitative data as well as general knowledge of the hazards in the community. Following is a summary of the hazard type, ranges of years where data was collected, frequency of the event (if known), total losses to date, probability of the event, average consequences in dollar amounts, average annualized loss and lastly the hazard rank.

Hazard Type	Year Start Range	Year End Range	Range	Frequency	Total Losses	Probability	Average Consequences	Average Annualized Loss	Risk
Dam Failure	0	0	0	0	$0	0.00	$0	$0	Severe
Flooding	1964	2010	46	41	$208,298,243	0.89	$5,080,445	$4,528,223	Severe
Severe Storm	1957	2010	53	169	$15,123,690	3.19	$89,489	$285,353	Severe
Severe Winter Storm	1960	2010	50	47	$11,623,778	0.94	$247,314	$232,476	Severe
Tornado	1960	2010	50	14	$15,000,384	0.28	$1,071,456	$300,008	Severe
HAZ/MAT	1986	2010	24	999	$0	41.63	$0	$0	Severe
Hail	1961	2010	49	46	$27,884,579	0.94	$606,187	$569,073	High
Karst/Sinkhole *	0	0	0	451 *	$0	0.00	$0	$0	High
Drought	1895	2010	115	29	$0	0.25	$0	$0	Moderate
Earthquake	0	0	0	0	$0	0.00	$0	$0	Moderate
Extreme Heat	1983	2010	27	11	$9,027	0.41	$821	$334	Moderate
Landslide	1990	2010	20	7	$98,851	0.35	$14,122	$4,943	Moderate
Wildfire	2000	2010	10	4	$0	0.40	$0	$0	Moderate
				TOTALS	**$256,921,700.00**		**$6,743,683.00**	**$5,495,145.00**	

**Karst Frequency is based on Sinkhole occurrences*

The Risk Matrix on the next page provides a qualitative assessment of various hazards that could occur. The extent of the hazard risk gauge ranges from yellow, indicating moderate, to red, indicating severe risk.

SEVERE RISK HAZARDS	DAM FAILURE FLOOD HAZ/MAT SEVERE STORM SEVERE WINTER STORM TORNADO
HIGH RISK HAZARDS	HAIL KARST/SINKHOLE
MODERATE RISK HAZARDS	DROUGHT EARTHQUAKE EXTREME HEAT LANDSLIDE WILDFIRE